Indian Science Congress Association

Silver Jubilee Session, 1938

AN OUTLINE
OF THE
FIELD SCIENCES OF INDIA

Edited by

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PREFACE.

The idea of publishing an outline of the Field Sciences of India, on the occasion of the Silver Jubilee Meeting of the Indian Science Congress Association, was suggested by Mr. W. D. West, the Honorary General Secretary of the Association and was readily accepted by its Executive and General Committees. The original intention of the author of the scheme was to help the foreign delegates to a proper appreciation of the manifold field problems involved in the study in India of such subjects as Meteorology, Oceanography, Geology, Botany, Zoology, Ethnology, Agriculture, Animal Husbandry and Archæology, and to enable them to make the best use of their short sojourn in this country. The publication was also intended to help the delegates to study any particular problem, in case they wished to do so, on the spot. The very title of the publication, however, denotes its scope, and those who may wish for more information on any of the subjects dealt with in the volume should refer to the detailed treatises made use of by the authors of the respective chapters.

It was a pleasant duty to collect the necessary material for this work. The readiness with which the authors responded to the invitation to contribute their respective chapters was most helpful. To fulfil its original purpose the work had to be produced within the short period of about 6 to 7 months, and it is hoped the readers will realize that under these limitations it was not possible to mould the various chapters to any general plan. Efforts were, however, made to bring about a certain amount of uniformity in the presentation of the material in each chapter and the Editor is greatly indebted to the authors who very kindly agreed to the suggestions made in this respect.

To make the text intelligible to general readers, each chapter is suitably illustrated. The number of illustrations, however, had to be restricted owing to the limited funds available. The coloured Orographic Map of India, which forms the frontispiece, should enable the readers not only to locate the various places referred to in each chapter, but will also give a clear idea of the physical features of the country, a knowledge of which is absolutely essential for a proper study of the field sciences.

It is hoped that the work as now presented will not only serve as a guide and a companion to all those who may wish to employ their leisure hours in the pursuit of the study of Field Sciences in this country, but will also enable the specialists in various branches of science to appreciate the problems of sister sciences. A composite publication of this nature is likely to have a wide influence in creating a broader outlook in the study of 'Science' as a whole, and may help to bring about a certain amount of

co-operation between workers in different branches which is so desirable for the advancement of science in these days of specialization and which is one of the main objects of the annual meetings of the Indian Science Congress Association.

To the students of science in India this publication is likely to be of great value and it is hoped that, in due course, it may stimulate among them a desire for work in the field. The true significance and value of the various subjects dealt with in this Outline can only be appreciated through an extensive study in the field and in this respect such a publication was hitherto a desideratum.

To achieve the above mentioned objects the Executive Committee of the Association has agreed to distribute copies of this publication, free of charge, to all Ordinary and Sessional Members of the Congress and to charge members of the other categories only a nominal price. Separates of the various chapters have also been published and will be available for sale almost at cost price.

The special thanks of the Editor are due, and are gratefully tendered, to Dr. B. Prashad and Mr. W. D. West for their kind help in various ways. The Science Congress Association is indebted to the Bombay Natural History Society, the Imperial Council of Agricultural Research, and the Director-General of Archæology in India for the loan of the majority of the blocks used to illustrate the chapters on Vegetation, Fauna, Agriculture and Animal Husbandry, and Archæology. Several other illustrations are reproduced by kind permission of the Director-General of Observatories, the Editor of the *Geological Magazine*, the Inspector-General of Forests, the Editor of the *Indian Forester*, the Imperial Council of Agricultural Research, and the Home Department of the Government of India. The sources of the various borrowed illustrations are fully acknowledged along with their explanations. The thanks of the Association are also due to the Surveyor General of India for supplying copies of the Orographic Map of India at a specially reduced rate.

The Association is indebted to the authorities of the Baptist Mission Press, Calcutta, especially to Messrs. P. Knight and N. A. Ellis, for their co-operation and help in the publication of the volume so expeditiously and in a manner characteristic of the reputation of this press.

Museum House,
Calcutta.
November, 1937.

SUNDER LAL HORA

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THE WEATHER OF INDIA.[1]

By

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CONTENTS.

Contrasts and Seasons

India presents as great contrasts in meteorological conditions as any area of similar size in the world, and furnishes the typical large-scale example of the alternation of seasons known as monsoons. The contrasts are striking. In the north-west lies the great Rajputana desert with average annual rainfall of less than 5 inches; in the north-east is Cherrapunji with an average annual rainfall of 430 inches. The observatory at Dras in Kashmir has recorded a temperature as low as $-49°$F.; that at Jacobabad has several times registered 126° and over. Hill stations in the Himalayas, such as Simla, may be shrouded in cloud for days together in September with humidities of 100 per cent., but in November may be overrun with air of practically zero humidity. The mean *annual* range of temperature at Cochin in South India, 20°F., is less than the *daily* range at many stations in North India and only about one-third of their annual range. During the winter third of the year the general flow of the surface air strata is from land to sea and thence over the Indian Seas as a *north-east monsoon*; it is a season of winds of continental origin and great dryness. The summer third of the year sees a complete reversal of this condition in a flow from sea to land of the moist winds of the *south-west*

[1] Largely a reprint of Chapter XVI of '*Souvenir—The Indian Empire*', (Calcutta, 1927), Congress of Far Eastern Association of Tropical Medicine. Also compare Chapter III in Vol. I, *Imperial Gazetteer of India*, (1907).

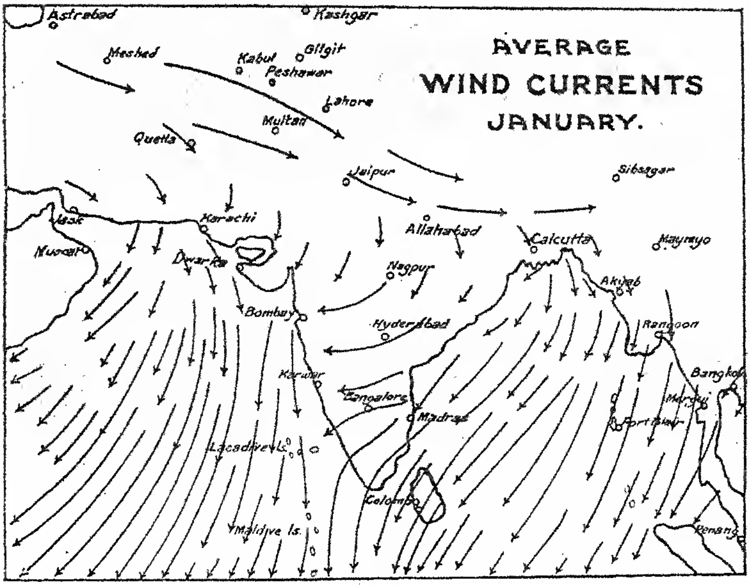
monsoon, which consequently is a season of much humidity and cloud and frequent rain. Between these principal seasons of the year are the transitional periods of the *hot weather* months, April and May, and of the *retreating south-west monsoon*, October and November. The causes determining the monsoon currents are many and complex but the fundamental cause is certainly the difference of temperature in the winter and summer months respectively between Southern Asia on the one hand and the Indian Ocean and China Seas on the other.

North-east Monsoon

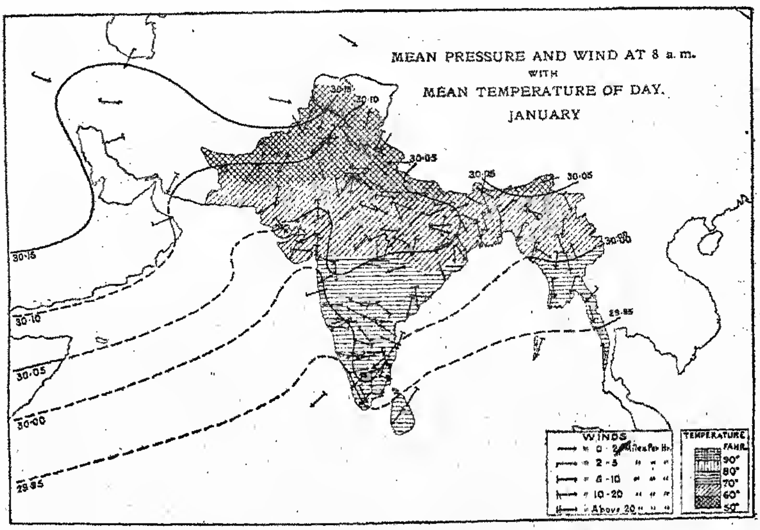
The North-east Monsoon is fully established over the Indian land and sea areas in the beginning of January (text-fig. 1), when Asiatic temperatures are at their lowest. There is then a belt of high pressure with anticyclonic conditions stretching from the West Mediterranean to Central Asia and North-east China. Clear skies, fine weather, low humidity, large diurnal range of temperature, and light northerly winds are the usual features of the weather in India during this period, broken only at intervals by weather disturbances which pass eastwards across Persia and Northern India, often into China. At Calcutta unfortunately the general fine weather of this season, with its evening and morning inversion of temperature in the lower atmosphere, often favours the formation of an evening blanket of smoke and morning mist. The western disturbances are ordinarily less intense than, but similar in type to, the depressions of European latitudes. The precipitation accompanying them is small in amount, but very important for the winter crops. Some in their eastward passage give light rains over the whole of Northern India, while others which confine their activity to the extreme north give moderate to heavy rain in the Punjab plains and heavy snowfall in the higher Himalayas. The disturbances are attended with marked temperature effects, a rise occurring in front of them, while in the rear unusually dry, clear weather prevails as a rule with stronger and cooler westerly winds. During this period of the year, rainfall is greatest in the north-west and decreases towards the south and east; dry weather prevails generally in the Peninsula and South Burma. The distribution of temperature (text-fig. 2) is almost similar to that of rainfall, weather being colder in the north-west than in the east and south.

Hot weather period

The hot weather period of March to May is one of continuous increase of temperature and decrease of barometric pressure in North India, of continuous decrease of temperature in the South Indian Ocean and adjacent land areas of Africa and Australia and of intensification of the southern anti-cyclonic high pressure area. There occurs a steady transference northward of the area of greatest heat in India, and simultaneously of the equatorial belt of lo pressure of the winter season. In March the highest day temperatures, about 100°F., occur in the Deccan; in April the area of



Text-fig. 1.—Sketch of average wind currents in January.

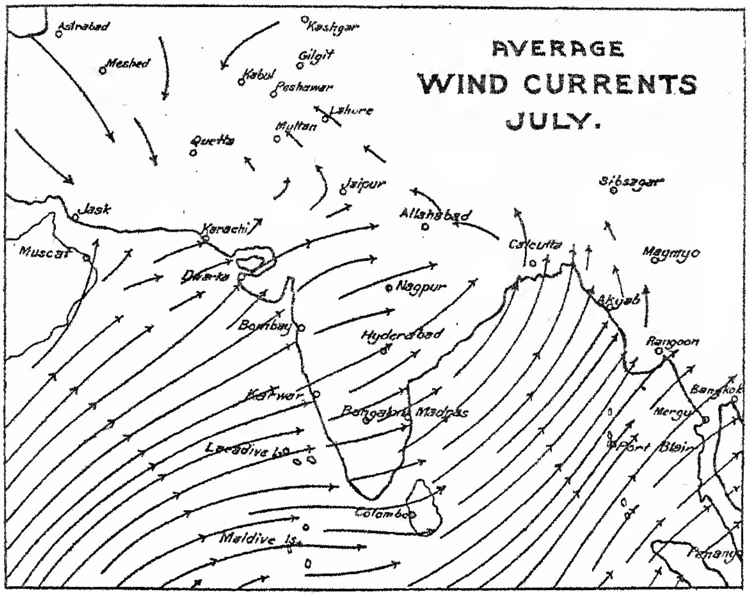


Text-fig. 2.—Pressure, temperature and wind directions in January.

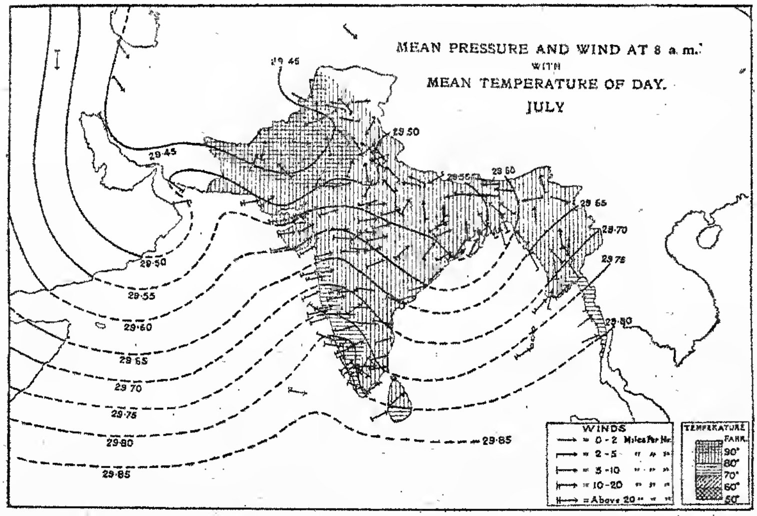
highest day temperatures, from 100° to 110°, lies over the south of the Central Provinces and Gujarat; while in May the seat of greatest heat is Northern India, and especially the north-west desert, where day temperatures of 120°F. or over are not infrequent. The area of lowest pressure also lies then over North-west India, with a trough stretching thence to Chota Nagpur. A local air circulation, with this trough as centre, exists over India and causes indraughts from the adjacent seas of southerly winds across the Bengal coast and of north-westerly winds across the Bombay coast. The land and sea winds give rise to large contrasts of temperature and humidity and consequently to violent local storms, especially in Bengal, where they are usually called "nor'-westers". These are sometimes of tornadic intensity and very destructive.

South-west Monsoon

Towards the end of May the air circulation over India becomes more and more vigorous, until, almost abruptly, the south-east trade winds from south of the equator are induced northwards into the Arabian Sea and Bay of Bengal and caught up in the Indian circulation. In most years this humid current, or the *south-west monsoon*, bursts on the Malabar coast during the first five days of June. It gradually extends northwards and is usually established over most of the Indian area by the end of June (text-fig. 3). The orographical features of India are of great importance in modifying the flow of the monsoon currents and the distribution of monsoon rainfall. The mountain ranges to the east and north of India are equivalent to two sides of a box, through the other two sides of which the monsoon currents stream. The southerly or Bay of Bengal current is naturally deflected by the two sides of the box northwards through Burma, and then westwards up the Gangetic Plain. The Arabian Sea current surmounts the Ghats on the west coast, causes copious rain there, advances over the Deccan and Central Provinces, and generally meets the Bay of Bengal current along the line of the trough of low pressure, which normally extends from Orissa to North-west India. Depressions which both intensify the monsoon rainfall and tend to concentrate it in their vicinity occasionally form in the north of the Bay and move along this trough (text-fig. 4). Further the trough is not stationary but moves north or south of the normal position and affects the rainfall distribution as it moves. Consequently the monsoon period is not one of continuous rain in any part of India. Bursts of general rain alternate with breaks partially or generally as the case may be. The pulsatory character of this action and of the rainfall precipitation is one of the most important features of the monsoon period meteorologically, as it is also economically for the proper growth of the crops. On the average, it may be said that the strength of the currents and the accompanying rainfall increase from June to July and remain steady till about the end of August. The monsoon then begins to retreat from Northern India. The table on page 6 shows



TEXT-FIG. 3.—Sketch of average wind currents in July.



TEXT-FIG. 4.—Pressure, temperature and wind directions in July.

the general distribution of rainfall month by month from May to October over the Indian land area :—

	Inches
May	3·1
June	7·9
July	11·2
August	10·3
September	7·0
October	3·3
TOTAL ..	42·8

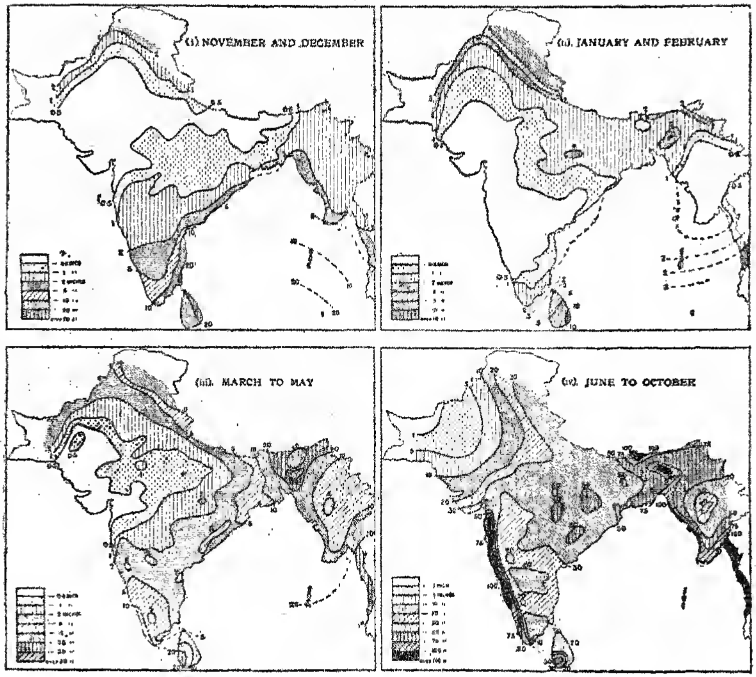
There are four important variations from the normal in the monsoon rains over the country; firstly, the beginning of the rains may be delayed considerably over the whole or a large part of India; secondly, there may be prolonged break or breaks lasting over the greater part of July or August; thirdly, the rains may end considerably earlier than usual, and lastly the rains may persist more than usual in one part of the country and consistently shun another. Consequences of the third variation are occasionally very serious and have been disastrous in the extreme in the famine areas, while the fourth constitutes the most common abnormality.

Retreating South-west Monsoon

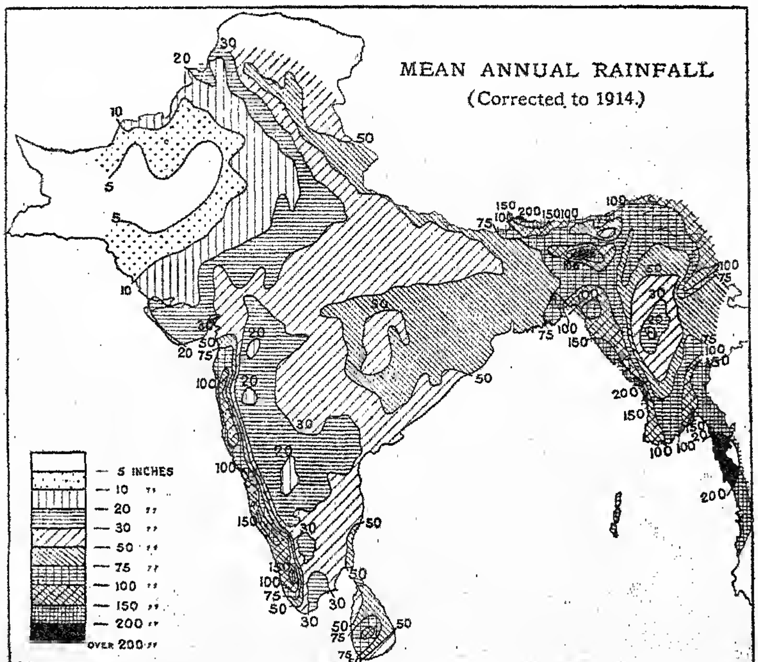
The second half of the wet season forms a period of transition leading up to the establishment of the conditions of the dry winter season. This transition begins in the early part of October and is usually not completed until mid-December. The Arabian Sea monsoon current retreats southwards from Rajputana, Gujarat and the Deccan by a series of intermittent actions. The Bay of Bengal current retreats similarly down the Gangetic Plain. The low pressure conditions previously prevailing in North India are obliterated by October, are transferred to the centre of the Bay at the beginning of November and to the south of the Bay by the beginning of December. By the end of that month the belt of low pressure usually passes out of the Bay limits into the equatorial belt where it forms a permanent feature of the meteorology of the Indian Ocean during the next five months. Similar conditions obtain in the Arabian Sea also. This retreat is associated with dry weather in Northern India but with more or less general rain on the coastal districts of Madras and over the eastern half of the Peninsula, where October and November are often the rainiest months of the year.

Rainfall Variations

From the foregoing description as well as from table A, it will be understood that the distribution of rainfall over India depends largely on its orographical features (text-fig. 5). If the hills and mountains of India were effaced, the country would receive much less rainfall and would not be able to support its present



TEXT-FIG. 5.—Mean Seasonal Rainfall.



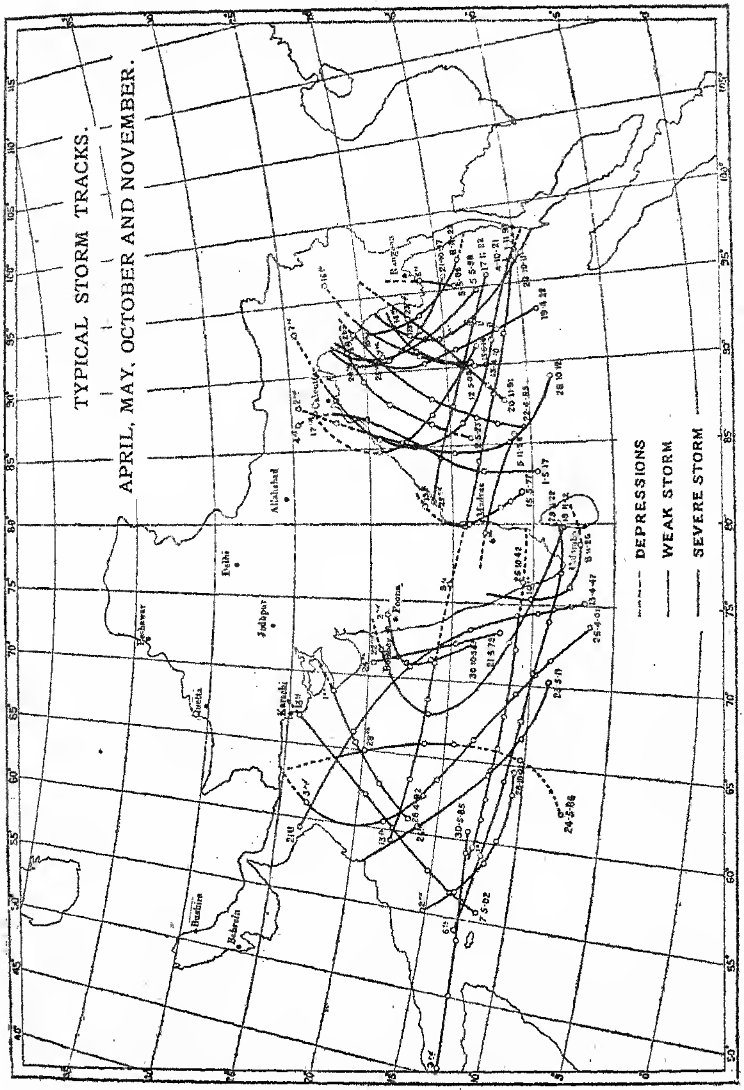
TEXT-FIG. 6.—Mean Annual Rainfall.

population. It will also be seen that the rainiest season in most provinces is the monsoon period, June to September; that rainfall during the cold weather is scanty but essential and economically important for the production of wheat crops over Northern India; and that the important rains in South-east Madras are those of October to December. Stress has also been laid on the great variability of monsoon rainfall in time and space in any one year. The variations in the amount of precipitation received from year to year are also surprisingly large. The average annual rainfall (text-fig. 6) of the Indian region, excluding Burma, is 42 inches and variations from this normal as great as +12 inches and −11 inches occurred in 1917 and 1899 respectively. Long breaks in the monsoon or an abrupt finish of the rains is disastrous to crops and produces droughts or famines. The droughts occur particularly in the interior districts, the percentage variability of annual rainfall being 100 per cent or even more in North-west India and parts of the Deccan. Droughts due to the failure of winter rains affect mostly the Punjab and the Gangetic Plain. The result of a drought may be scarcity or famine, either local or widespread. Famine, however, though once 'the bogey of the Indian administrator' is no longer the nightmare that it was, because the effects of a drought of any particular intensity have been minimised in the past 60 years by the famine-relief system, the spread of irrigation, the network of railways and improvements in dry-farming.

On the other hand, tracts of country are sometimes deluged with rain and suffer distress through excessive flooding. The heavy downpours occur chiefly near the tracks of the cyclonic depressions of the monsoon months or of the cyclones that occasionally advance inland from the Bay of Bengal or Arabian Sea. A fall of 10 inches to 20 inches in a day is by no means a rare occurrence. The heaviest ever recorded in the plains in 24 hours is 35 inches at Purnea in Bihar.

Cyclones

At a time when the general meteorology of India was unknown, Henry Piddington laid the foundations of our knowledge of the storms of the Indian Seas and introduced the word *cyclones* to connote them. In these storms, oval or circular in shape, the air moves in converging spirals in a left-handed direction against the hands of a clock. The winds become fiercer and fiercer as the centre is approached and reach hurricane force near it. In the innermost central zone of some ten miles diameter the wind suddenly falls off to a calm or light air, and the barometric pressure there often marks an inch, and sometimes as much as two inches, below normal. Cyclones generally die away soon after they reach land, but in the coastal districts which they touch may cause great havoc through high winds, torrential rain and, most destructive of all in low-lying districts, storm waves (text-fig. 7). The latter are due to the huge masses of sea-water swept forward by the storms and, when aided by a high



TEXT-FIG. 7.—Tracks of Cyclones in Indian Seas.

tide, may inundate low-lying land to a depth of 20 feet. The storm wave accompanying the Bakarganj cyclone of 1876 was one of the most destructive on record; about a hundred thousand people were drowned in half-an-hour on the alluvial flats of the Meghna, while an equal number died from epidemics of fever, cholera and other diseases, which almost invariably follow a storm wave. The principal cyclone months in both the Arabian Sea and Bay of Bengal are May, October and November. They may also occur in April, September and December, and, particularly in the Arabian Sea, in June on the advancing front of monsoon air.

Temperature and Climates

Temperature is perhaps, next to rainfall, the most important feature of meteorological observations in India from the economic standpoint. During one part of the year from January to May or June the increase of temperature by solar action is greater than the loss by radiation and other actions, and hence temperature rises more or less steadily in conformity with the increasing elevation of the sun. During the remainder of the year, the balance is the other way and temperature steadily decreases from June or July to December. Though, in most countries July and August are as hot as, or hotter than, June, the similar phenomenon is prevented in India by the cloud and rains of the south-west monsoon. The annual variation of temperature is small in the extreme south and increases rather rapidly northwards; proceeding along the east and west coast of India, it is twice as great at Bombay and Rangoon as in Malabar and over four times as great at Karachi. It is from eight to ten times as great at stations in the North Deccan and Northern and Central India and is absolutely greatest in the most inland of the driest tracts, including Upper Sind and the Punjab. The difference between the minimum and maximum temperatures on a day, called the diurnal range, is much smaller in the wet than in the dry season and at coastal stations than in the interior. It is about 10°F. on the west coast of the Peninsula, and rises to 30°F. on the mean of the year in the Punjab and Upper Sind.

As already indicated in the opening paragraph, different parts of India exhibit very great diversity in respect of their climatic features. Northern or extra-tropical India alone, in its most easterly and most westerly provinces, in Assam on the one hand and in Sind on the other, presents us with the greatest possible contrast of dampness and dryness, a contrast greater than that of the British Isles and Egypt; and when, further, we compare the most northerly province, the Punjab, with the most southerly, such as Travancore or Tenasserim, we have in the former a continental climate of the most pronounced character, extreme summer heat alternating with winter cold that sometimes sinks to freezing-point, and in the latter an almost unvarying warmth in conjunction with a uniformly moist atmosphere, that is especially characteristic of the shores of a tropical sea. In addition to this heterogeneity on the plains,

there is a further variety due to the hills. Indeed, from a sanitary point of view and as health resorts, the climates of hill stations deserve special mention. These stations are situated along the Himalayas and on the Ghats in the Peninsula. In all cases their atmosphere is cooler and damper than that of the neighbouring plains; but while those in the North-West Himalaya are subject to great vicissitudes of heat and cold, dryness and dampness in the course of the year, those of Southern India and Ceylon are comparatively equable, and their fine clear season is shorter than at the northern stations, and by no means so dry. In table B are given the temperature data for a few hill stations, as well as for selected stations in the plains.

(The India Meteorological Department publishes *Daily Weather Reports* in Poona, Calcutta, and Karachi; the *Indian Monthly Weather Report; Annual Summary;* and seasonal forecasts of monsoon and winter rains. The scientific work of the department is published in departmental *Memoirs, Scientific Notes* and in various atlases and handbooks).

TABLE A.

Monthly and Annual Normal Rainfall by Divisions.

Divisions	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Lower Burma	0·12	0·23	0·55	1·42	12·30	25·79	29·77	27·50	17·61	7·85	2·71	0·54	126·39
Upper Burma	0·10	0·21	0·42	1·29	5·98	8·11	7·35	8·63	8·03	5·55	1·82	0·47	47·96
Assam	0·67	1·53	4·00	9·00	12·08	18·23	18·74	16·83	12·50	5·66	0·90	0·35	100·49
Bengal	0·34	0·95	1·67	3·25	7·64	14·62	15·14	14·26	10·89	5·08	0·79	0·16	74·79
Orissa	0·44	1·17	1·08	1·38	3·31	9·83	13·01	13·00	8·96	4·88	1·52	0·22	58·80
Chota Nagpur	0·77	1·15	0·93	0·70	2·13	8·97	12·91	13·77	8·10	2·92	0·39	0·14	52·88
Bihar	0·42	0·69	0·47	0·60	2·27	7·78	12·36	12·51	8·80	2·32	0·29	0·09	48·60
United Provinces, East ..	0·63	0·55	0·32	0·19	0·67	4·78	11·55	11·33	6·87	1·87	0·19	0·22	39·17
United Provinces, West ..	0·96	0·89	0·61	0·30	0·68	4·06	11·47	11·14	5·96	0·88	0·15	0·36	37·46
Punjab, East and North ..	1·21	1·02	0·91	0·56	0·62	2·02	6·22	6·37	3·30	0·38	0·13	0·44	23·18
Punjab, South-west ..	0·50	0·53	0·64	0·52	0·42	0·81	2·47	2·56	1·11	0·10	0·08	0·21	9·95
Kashmir	3·71	3·54	4·60	3·45	1·93	2·53	7·26	7·86	3·60	1·05	0·48	1·97	41·98
N.-W. Frontier Province ..	1·28	1·19	1·89	1·54	0·77	0·86	2·58	3·16	1·18	0·33	0·28	0·54	15·60
Baluchistan	1·18	1·19	1·24	0·68	0·27	0·30	0·98	1·00	0·25	0·15	0·26	0 62	8·12
Sind	0·11	0·18	0·18	0·10	0·25	0·34	1·64	2·20	0·96	0·14	0·02	0·07	6·19
Rajputana, West ..	0·19	0·23	0·18	0·16	0·44	1·31	3·43	4·07	2·04	0·32	0·08	0·10	12·55
Rajputana, East ..	0·37	0·31	0·24	0 17	0·52	2·62	8·31	8·14	3·96	0·52	0·16	0·22	25·54
Gujarat	0·09	0·10	0·07	0·03	0·33	5·15	12·61	8·11	4·64	0·91	0·20	0·04	32·28
Central India, West ..	0·38	0·30	0·16	0·15	0·47	4·78	10·52	10·97	5·21	0·80	0·41	0·16	34·31
Central India, East	0·56	0·63	0·33	0·22	0·43	4·50	12·04	12·49	6·36	1·17	0·35	0·21	39·29

Berar	0·39	0·35	0·33	0·24	0·54	6·05	9·12	6·91	5·80	1·57	0·57	0·39	32·26
Central Provinces, West ..	0·65	0·71	0·59	0·31	0·59	7·39	13·44	12·91	7·60	1·82	0·56	0·30	46·87
Central Provinces, East ..	0·46	1·11	0·60	0·73	0·79	9·32	15·27	14·93	7·59	2·25	0·40	0·29	53·74
Konkan	0·10	0·05	0·06	0·36	1·55	25·31	39·09	23·99	12·53	4·30	1·01	0·13	108·48
Bombay Deccan ..	0·15	0·08	0·15	0·63	1·35	5·22	7·85	5·44	5·61	3·02	1·01	0·28	30·79
Hyderabad, North ..	0·16	0·25	0·37	0·51	0·73	5·51	8·00	7·23	8·10	2·30	0·77	0·36	34·29
Hyderabad, South ..	0·18	0·24	0·42	0·81	1·02	4·33	6·24	6·31	6·82	3·02	1·06	0·22	30·67
Mysore	0·12	0·13	0·31	1·46	3·58	4·80	7·15	5·23	5·18	5·30	2·42	0·45	36·13
Malabar	0·92	0·57	1·50	3·84	7·39	23·82	21·50	12·16	7·85	11·33	7·36	1·86	100·10
Madras, South-east ..	0·98	0·47	0·51	1·29	2·53	1·56	2·19	3·61	4·48	7·10	7·47	3·38	35·57
Madras, Deccan ..	0·20	0·14	0·21	0·62	1·67	2·36	3·21	3·91	5·75	4·18	2·18	0·41	24·84
Madras Coast, North ..	0·38	0·39	0·50	0·93	2·10	4·91	6·61	7·07	6·96	6·75	3·69	0·85	41·14

TABLE B.

Mean Maximum and Minimum Temperatures in Fahrenheit.

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum	Lowest Minimum
Karachi (Drigh Road)	78·3 *51·2*	80·5 *54·5*	89·5 *62·1*	94·7 *71·5*	94·8 *77·5*	94·0 *82·0*	91·2 *81·1*	87·8 *78·6*	89·8 *76·2*	95·1 *68·7*	89·7 *59·2*	80·8 *52·7*	116·3	31·4
Jodhpur ..	76·9 *50·5*	80·6 *53·3*	90·9 *62·7*	100·2 *72·5*	106·0 *79·8*	103·8 *82·2*	97·5 *80·3*	93·1 *77·7*	94·8 *75·5*	96·4 *67·8*	88·8 *58·6*	79·6 *52·2*	121·3	28·1
Delhi ..	70·0 *47·9*	74·6 *51·7*	86·0 *61·6*	97·9 *72·8*	104·0 *80·2*	103·3 *83·6*	94·9 *81·1*	92·4 *79·8*	93·0 *77·1*	91·6 *68·4*	82·2 *56·7*	72·9 *48·9*	118·0	32·5
Agra ..	74·2 *43·8*	78·5 *46·9*	90·2 *55·8*	101·7 *67·8*	107·5 *77·0*	105·0 *83·4*	95·0 *80·2*	91·7 *78·9*	93·1 *75·6*	92·9 *62·7*	85·5 *49·5*	76·9 *44·4*	120·3	33·9
Allahabad ..	74·4 *48·0*	79·5 *51·9*	91·9 *61·7*	102·8 *72·0*	106·6 *79·6*	102·1 *82·7*	92·8 *79·8*	90·0 *78·6*	91·5 *76·9*	91·1 *67·5*	83·4 *55·3*	75·7 *47·7*	119·8	34·1
Jubbulpore ..	77·5 *48·6*	81·5 *52·4*	91·8 *60·5*	100·8 *70·2*	105·3 *78·5*	97·8 *78·9*	86·7 *75·0*	84·6 *74·0*	87·2 *72·8*	87·7 *64·2*	82·0 *53·2*	77·0 *46·7*	114·8	31·9
Patna ..	72·7 *50·9*	77·5 *54·2*	89·5 *63·9*	99·0 *73·3*	99·7 *77·7*	95·7 *79·8*	90·5 *79·8*	89·1 *79·4*	89·5 *78·8*	88·4 *72·8*	81·7 *61·0*	74·1 *51·8*	114·4	36·3
Calcutta ..	77·5 *55·6*	82·3 *60·3*	91·0 *69·4*	95·5 *75·7*	94·6 *77·6*	91·3 *78·8*	98·6 *78·7*	87·8 *78·5*	88·2 *78·1*	87·4 *74·5*	82·2 *64·7*	77·0 *56·0*	108·2	44·2
Tezpur ..	73·6 *52·4*	76·0 *55·7*	82·6 *61·8*	83·4 *67·1*	86·9 *72·3*	88·8 *76·6*	89·2 *77·6*	89·0 *77·7*	88·6 *76·5*	85·8 *71·1*	80·5 *61·4*	74·5 *53·5*	98·1	42·8
Mandalay ..	84·5 *56·6*	90·3 *60·1*	98·1 *68·3*	102·4 *77·3*	99·8 *79·0*	94·8 *78·6*	94·7 *78·6*	93·2 *77·9*	93·1 *77·1*	92·0 *74·7*	87·7 *67·9*	83·5 *59·4*	113·6	45·1

Akyab ..	80·8 *59·3*	84·3 *61·2*	88·5 *68·5*	91·3 *75·3*	90·5 *77·7*	86·0 *77·5*	84·6 *77·0*	84·6 *76·9*	86·4 *77·4*	87·3 *76·2*	84·7 *70·9*	80·7 *63·1*	100·1	47·3
Rangoon ..	88·6 *64·9*	92·3 *66·5*	95·9 *71·2*	98·0 *76·1*	91·7 *77·2*	86·4 *76·4*	85·3 *75·8*	85·0 *75·8*	85·9 *76·0*	87·6 *75·8*	87·5 *72·7*	87·1 *67·4*	106·4	55·3
Bombay ..	82·9 *66·7*	82·9 *67·2*	85·8 *71·6*	88·5 *75·7*	90·8 *79·3*	88·3 *78·4*	85·4 *76·5*	84·9 *75·9*	85·3 *75·5*	88·7 *75·4*	89·2 *72·3*	86·4 *68·5*	100·0	55·9
Nagpur ..	83·5 *55·6*	88·5 *59·6*	97·4 *67·2*	104·8 *75·7*	108·6 *81·8*	98·9 *79·0*	88·1 *75·3*	86·8 *74·6*	89·1 *73·8*	90·6 *68·3*	85·6 *60·0*	81·7 *54·2*	117·7	39·4
Ahmadabad ..	84·8 *57·7*	87·8 *59·5*	96·9 *67·2*	104·3 *74·4*	107·4 *79·2*	101·3 *80·9*	93·1 *78·5*	90·0 *76·8*	92·9 *76·1*	97·3 *72·4*	92·9 *65·5*	86·4 *59·3*	117·8	36·0
Poona ..	86·1 *53·3*	90·6 *55·2*	97·1 *62·1*	101·1 *68·9*	98·8 *73·0*	89·0 *74·0*	82·8 *71·9*	81·7 *70·5*	84·0 *69·1*	89·4 *66·5*	86·5 *58·9*	84·7 *53·0*	110·0	38·8
Hyderabad, Deccan (Begumpet). ..	84·2 *59·9*	89·7 *64·2*	96·7 *70·1*	101·2 *76·2*	103·1 *80·0*	94·5 *76·1*	87·6 *73·3*	85·8 *72·5*	86·4 *72·3*	88·4 *69·4*	84·5 *63·2*	82·4 *58·3*	111·9	47·3
Bangalore ..	80·8 *57·5*	86·2 *60·2*	91·1 *64·8*	93·5 *69·4*	91·7 *69·2*	84·9 *66·9*	82·2 *66·0*	82·0 *65·8*	82·3 *65·6*	82·1 *65·2*	79·8 *62·2*	78·9 *58·5*	100·8	45·8
Madras ..	85·2 *67·3*	87·1 *68·0*	89·5 *71·7*	92·4 *77·1*	97·9 *80·9*	98·3 *80·6*	95·3 *78·5*	93·7 *77·2*	92·7 *76·6*	89·6 *74·6*	85·7 *71·9*	83·9 *69·3*	113·0	57·5
Waltair (Vizagapatam)	80·8 *67·9*	83·8 *71·1*	87·3 *74·7*	89·7 *78·3*	92·0 *80·8*	91·2 *80·2*	89·0 *78·6*	88·8 *78·2*	88·4 *78·1*	88·0 *76·4*	84·3 *72·7*	80·8 *68·1*	111·4	59·6
Mangalore ..	89·2 *70·6*	88·6 *72·3*	90·1 *75·7*	91·7 *78·4*	91·3 *78·7*	85·3 *74·6*	83·9 *74·1*	83·7 *74·1*	84·5 *74·1*	86·1 *74·5*	88·2 *73·4*	89·3 *70·8*	100·1	59·8
Trivandrum ..	84·0 *72·3*	85·6 *73·7*	87·6 *76·5*	88·0 *78·2*	86·7 *77·9*	83·1 *75·6*	82·2 *74·8*	82·5 *74·8*	83·1 *75·0*	83·0 *74·9*	82·8 *74·1*	83·3 *72·9*	93·5	63·0
Quetta ..	50·1 *30·4*	52·5 *32·8*	63·1 *40·3*	73·4 *48·0*	84·7 *55·5*	92·0 *62·1*	93·7 *68·1*	91·9 *65·6*	85·8 *54·1*	74·5 *42·8*	64·1 *34·7*	54·9 *31·0*	103·9	3·0

Mean Maximum and Minimum Temperatures in Fahrenheit.

Table B (continued).

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum	Lowest Minimum
Peshawar ..	63·4 *40·8*	66·2 *43·8*	74·5 *52·1*	84·9 *60·4*	96·8 *70·2*	104·8 *77·3*	102·2 *79·8*	98·2 *78·5*	94·8 *71·4*	87·9 *60·3*	76·5 *48·9*	66·6 *40·5*	121·6	24·7
Lahore ..	68·9 *40·2*	72·4 *43·8*	82·9 *52·9*	95·0 *62·8*	103·9 *71·8*	106·2 *78·7*	99·9 *79·7*	97·3 *78·4*	97·5 *72·7*	94·6 *59·2*	83·4 *46·8*	72·9 *39·8*	120·3	29·2
Rawalpindi ..	62·7 *38·1*	65·1 *41·3*	75·0 *50·3*	86·3 *59·1*	97·9 *68·3*	103·6 *75·7*	97·9 *76·8*	93·9 *75·4*	93·4 *69·1*	88·8 *56·6*	77·5 *44·2*	66·8 *37·4*	118·0	23·9
Simla ..	47·5 *35·2*	48·4 *35·6*	56·5 *43·1*	66·3 *50·3*	73·6 *57·4*	75·0 *59·6*	71·3 *58·9*	68·7 *59·2*	68·7 *56·3*	64·4 *51·4*	58·4 *43·9*	50·1 *39·2*	94·4	17·1
Ootacamund ..	65·6 *43·0*	67·4 *44·0*	70·0 *47·8*	71·7 *51·5*	70·2 *52·4*	64·3 *52·3*	62·1 *52·0*	62·9 *51·7*	64·4 *51·1*	64·6 *50·5*	63·6 *48·0*	64·8 *44·3*	78·0	30·5
Kodaikanal ..	62·0 *46·7*	64·1 *47·5*	66·1 *50·5*	68·2 *53·5*	67·9 *54·6*	64·2 *53·1*	61·9 *52·1*	62·4 *51·8*	62·1 *52·0*	61·8 *51·1*	60·7 *49·2*	61·6 *47·4*	78·0	37·1
Darjeeling ..	47·3 *35·1*	48·9 *36·1*	56·5 *42·3*	62·5 *48·4*	64·6 *52·3*	66·2 *56·5*	66·8 *58·0*	66·5 *57·6*	65·4 *55·9*	61·7 *50·1*	55·6 *42·8*	49·4 *36·7*	80·1	19·9
Mussooree ..	48·3 *37·3*	50·1 *37·7*	60·4 *45·3*	71·1 *53·5*	77·3 *58·7*	76·9 *61·3*	71·2 *60·7*	69·0 *59·9*	68·3 *57·2*	64·9 *51·4*	57·8 *45·5*	51·2 *40·1*	93·3	21·0
Pachmarhi ..	71·8 *47·6*	75·2 *51·0*	84·1 *59·8*	92·0 *69·3*	95·5 *75·0*	87·4 *72·1*	76·7 *68·2*	74·8 *67·0*	77·5 *66·2*	79·0 *59·5*	74·2 *51·0*	70·8 *45·8*	105·0	30·0

THE OCEANS ROUND INDIA.

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CONTENTS.

INTRODUCTION.

Until Geologists are able to come to some final conclusion regarding the past history of the earth it is impossible for the Oceanographer to formulate a definite theory concerning the origin of any of the great oceans of the present day. In this respect the Indian Ocean presents a particularly difficult problem owing to the diametrically opposed views held by two schools of thought. Biologists and Geologists in the past have not hesitated to put forward theories regarding the previous existence, and subsequent disappearance below the sea, of large areas of land in order to account for a similarity in either the fossil or the living fauna and flora of lands that are now separated by wide stretches of sea and ocean. According to this school of thought, practically the whole of the region that is now the Indian Ocean and the area to the North of it was at the close of the Palæozoic Era, in Permo-carboniferous

times, occupied by two separate masses of land, the great continent of Angara, covered by the 'Gigantopteris' type of flora, stretching from east to west across the northern part of the hemisphere and the corresponding southern continent of Gondwana, characterized by the 'Glossopteris' flora, extending from Australia through Peninsular India and South Africa on to South America; between these two great continental masses ran a comparatively narrow sea that stretched from east to west uniting the Atlantic and Pacific Oceanic areas. At the close of the Mesozoic Era the great continent of Gondwanaland is supposed to have broken up, large areas foundering beneath the ocean, so that Australia, India, South Africa and South America became separated, the last completely; but India and Africa are supposed to have been still connected by an isthmus bridge, to which the name 'Lemuria' has been given, that followed a somewhat zig-zag course and the line of which is to the upholders of this theory still indicated by the position of Madagascar, the Seychelles, Mauritius, Réunion and the Chagos, Maldive and Laccadive Archipelagoes. Similarly, on the east side of India a large area of land, traversed by a mountain belt to which the name Madras Mountain belt has been given, is supposed to have extended eastward, possibly as far as the Andaman Islands, and occupied the area that is now the Bay of Bengal. In Permian times this land area together with Peninsular India formed, according to this view, an elevated region that drained northwards and was bounded on its east side by a great sea that extended northwards from Tenasserim to Assam and then westwards to the Punjab. In the Jurassic epoch this eastward extension of the Indian Peninsula, still traversed by the Madras mountain belt which by now had been considerably eroded, is supposed to have undergone subsidence and sank beneath the sea, thus giving rise to the fore-runner of the Bay of Bengal. About the same time the central part of the great continent of Angara is also supposed to have subsided, so that a great sea then extended from north to south and united the Arctic Ocean with the great tropical ocean that had drowned the greater part of Gondwanaland.

According to the second view, that was put forward by Wegener and is known by the name of the 'Drift theory', all the great continents of the present day were originally parts of one vast land mass, that later became split up into fragments; gradually these masses drifted apart, leaving the ocean basins as we see them to-day.

Whichever school of thought we may follow, at the close of the Mesozoic Era the Indian Ocean was composed of a northern and a southern part, in a manner that very closely resembled the Atlantic and Pacific Oceans of the present day, while from east to west a circum-terrestrial sea, the Tethys, passed to the north of Arabia and India, terminating in what is now the Bay of Bengal, and thus connected the Atlantic with the Indian Ocean;

further to the south-east there was a wide and probably deep connection between the Indian and Pacific Oceans, passing between Asia and Australia. There was thus a highway, not only from east to west, or *vice versa*, but also from north to south, along which the marine fauna and flora could extend from ocean to ocean so long as they were capable of surviving the differences of temperature and the competition of other already established forms and species.

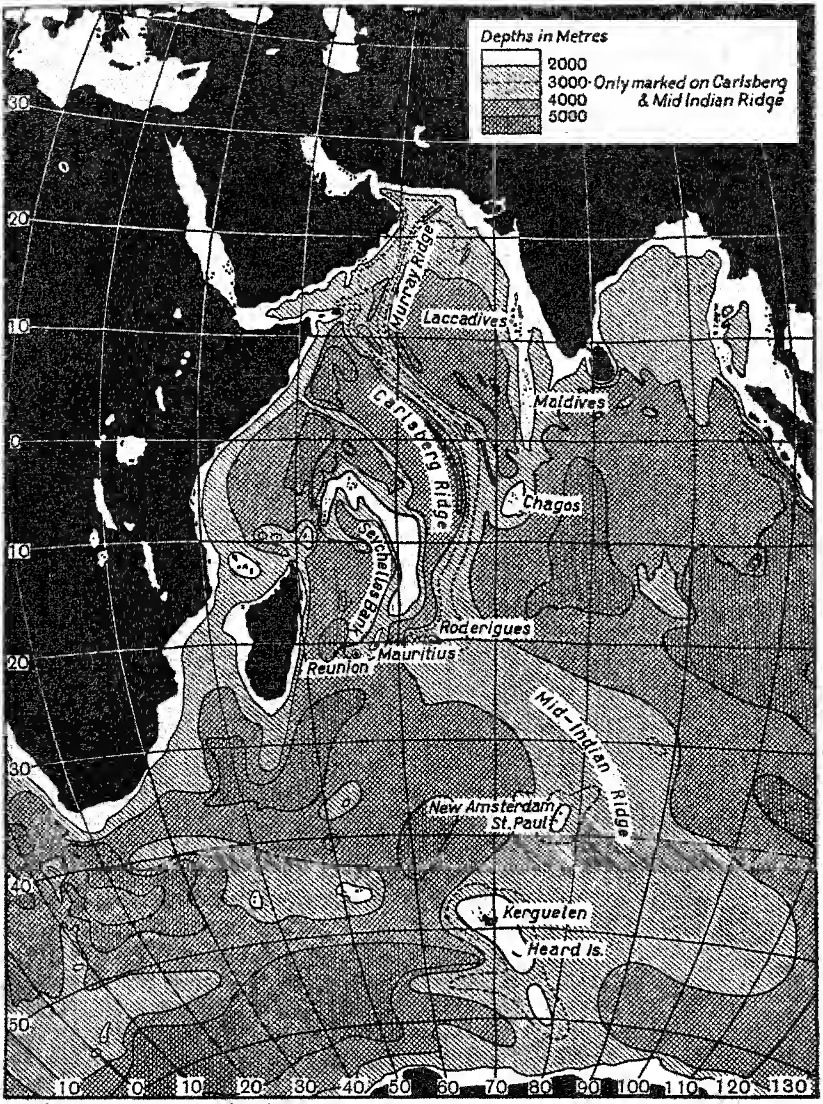
At the commencement of the Kainozoic Era, in Eocene and Miocene times, the great circum-terrestrial Tethys Sea began to be slowly but surely interrupted by the gradual uprising of the great Alpine-Himalayan mountain range; at first this interruption was but slight, taking the form of scattered islands, but as the upheaval continued the sea became transformed into a series of lagoons or a chain of more or less land-locked lakes, the original sites of which are perhaps indicated at the present day by the great petroleum-bearing regions; and finally even these were filled in. At the same time the upheaval of the Malayan arc caused a great obstruction to the free passage between the Pacific and the south-east part of the Indian Ocean. At or about the same period the gradual upheaval of the central Asian plateau caused the obliteration of the northern part of the Indian Ocean, so that to-day the only traces of its original vast extent are to be found in the Gulf of Oman and the Persian Gulf, and the great lakes of Asia, the Caspian Sea, the Aral Sea, etc. How far towards the south this upheaval of the Asiatic continent affected the Indian Ocean is not yet determined; but it seems probable that at the close of the Miocene a mass of land occupied the area between India, Arabia and north-east Africa, so that at that time there was as yet no Gulf of Aden or Red Sea, though these were beginning to be formed by the gradual development of the great African Rift, extending in a zig-zag direction from north to south between Palestine and Syria, then between Egypt and Arabia, and finally down the east side of Africa where the great African Lakes lie at the present day. Similarly, it has been suggested that even as late as Miocene times a vast tract of land once again extended eastward from India to the neighbourhood of the Andaman Islands, so that the Bay of Bengal was again obliterated.

Topography. (Figure 1).

At the present day India, with the island of Ceylon lying off its southern point, forms a triangle of land thrusting southwards into the Indian Ocean and thus dividing its northern area into two parts, the Bay of Bengal on the east and the Arabian Sea on the west. Each of these areas is again subdivided by a range of islands into a main area and a subsidiary region; to the east of the Bay of Bengal the curved chain of the Andaman and Nicobar Islands forms the

western boundary of the Andaman Sea basin and on the south-west of India the straight north-south line of the Laccadive, Maldive and Chagos Archipelagoes forms the western limit of the Laccadive Sea. Each chain of islands marks the line of a great submarine mountain range, but there is this great difference between the two; in the Andaman-Nicobar chain the islands are themselves the topmost peaks of the range, whereas in the Laccadive, Maldive and Chagos Archipelagoes the islands are composed entirely of coral that has grown up and now covers the mountain peaks, the actual topmost points of the range being at some and possibly a great depth below the surface. In the course of this growth the coral has here formed one of the finest series of atolls and lagoons in the world.

Running from north to south down the Bay of Bengal to the west of the Andaman-Nicobar Islands is a submarine ridge, named Carpenter's Ridge, that rises from the sea-floor up to about 2,280 metres or less and having water of some 3,650 metres on either side of it. It is probable that this ridge arose simultaneously with the Andaman arc and that both are parts of the Malayan arc that arose in Eocene-Miocene times contemporaneously with the Alpine-Himalayan system. To the east of the Andaman-Nicobar Islands lies a volcanic range that is in all probability Tertiary in age and is continuous with the series of volcanoes of Sumatra and Java; in the Nicobar region this volcanic range is inextricably blended with the non-volcanic range of the Andaman arc but further to the north the two ranges diverge and the volcanic range trends towards the north-east, its course being indicated possibly by 'Invisible Bank', that lies just to the east of Little Andaman Island and almost reaches the surface, and certainly by the bank from which the nearly extinct volcano Barren Island arises, while the extinct volcano Narkondam rises from the sea-floor as a western outlier: finally, this volcanic range runs through Burma between the Irrawaddi and Salween valleys, past the recently extinct volcano Mount Popa and on into the Shan States and Yunnan. The fact that Barren Island still possesses a warm spring, while Mount Popa has according to tradition only recently become extinct, suggests that the whole of this part of the volcanic range was active in comparatively recent times. It would seem probable that the Andaman Sea itself is of comparatively recent origin and that originally it extended much further to the northward. The geological features of the Irrawaddi valley indicate that this region was slowly but surely, if irregularly, undergoing subsidence and this is in all probability true of the whole Andaman Sea basin. This subsidence appears to have affected the Andaman-Nicobar chain for the topmost peaks of the range commence with a height of some 8,000 feet above sea-level at Chypotong in the Arakan Range but fall to only 150 feet above sea-level on Batti Malv in the Nicobars and then rise again to



TEXT-FIG. 1.—Bathymetric Chart of the Indian Ocean.

(Reprinted from *Geol. Mag.*, LXXIV, 1937, after slight modification.)

12,000 feet at Sinobong in Sumatra. Further eastward examination of the sea-floor has revealed the presence of an interrupted line of rock that runs almost parallel with the present coast of Burma and that lies at a depth of about 141 metres at the northern end but gradually sinks, as we trace it southward, till at its southern end near the island of Sumatra in Lat. 8° 52′ N., Long. 96° 29′ E. it is covered by 417 metres of water ; several isolated banks rise nearly to the surface, thus Heckford Bank lies at a depth of only 13 metres, Coral Bank at 20 metres and Roe Bank at 15 metres, but at no point does the ridge actually break the surface. It seems probable that this is an arc of the Malayan Ranges that has become submerged since its upheaval in Tertiary times.

The nature of the bases on which the Laccadive, Maldive and Chagos Archipelagoes respectively are perched can only be guessed, since there is no true land in any island of these groups ; indeed it seems possible that the two extremes of the chain may have had different origins, for the recent work of Lieut.-Col. E. A. Glennie, R.E., D.S.O., of the Survey of India, on the geodetic character of the Laccadive and Maldive groups has proved that this differs in the two Archipelagoes, a positive variation being found in the former and a negative in the latter. Glennie draws the conclusion that the Laccadives are perched on an upthrust, that may be a continuation of the Aravalli Mountain Chain, the oldest mountain range in India and dating back to the Permo-Carboniferous Era ; the Maldives he believes, on the other hand, to be situated on a deep-seated down-warping, and the actual ridge may perhaps be volcanic in origin, as suggested by Murray and others. Whatever the nature of the basic rock of these ridges may be, it is not improbable that they were once a part of the mainland and became separated off from India and Ceylon by a fault, the line of which is now marked by the Laccadive Sea, and, if we accept the Drift Theory of Wegener, were left behind and became submerged when India drifted away towards the north-east.

To the west between India and Africa recent topographical investigations have revealed the existence of a great submarine mountain chain, the Carlsberg Ridge, that rises from the sea-floor, with a depth of some 5,300 metres on its south-west side and of 5,120 metres on the north-east, to a height of at least 12,000 feet, soundings as shallow as 1,550 metres having been obtained in about Lat. 1° N. and again in about Lat. 10° N. This great ridge, which appears to be double throughout the greater part of its length, two high ridges enclosing between them a deep gulley in which the depth is some 3,380–3,660 metres, commences in the vicinity of the island of Socotra and Cape Guardafui and runs at first towards the south-east to near the Chagos Archipelago, where it bends at first south and then west of south and, so far as the few soundings indicate, is continued as far as the island of Rodriguez. At this point the ridge loses its great height but, in all probability, is con-

tinued on at a lower level to constitute a Mid-Indian Ridge, that appears closely to resemble the corresponding ridge down the middle of the Atlantic Ocean; further to the south this ridge expands into a wide plateau from which the islands of New Amsterdam and St. Paul rise from one base and the islands of Kerguelen, Heard and Macdonald from a second, to which the name Kerguelen-Gaussberg Ridge has been given; finally the ridge blends with the Antarctic continent. At its north-western extremity there is some indication that the Carlsberg Ridge is continued towards the north-east to join a ridge that has recently been discovered by the John Murray Expedition and to which the name Murray Ridge has been given; this second ridge is also double in character, enclosing a deep gulley along which the depth is some 3,660 metres while the banks on either side are covered by water of a depth of only 550–730 metres, and passing in a north-easterly direction across the entrance to the Gulf of Oman it joins the coast of India a little to the north of Karachi and seems to be a submarine continuation of the Kirthar Range of Sind. Running from east to west along the coast of Baluchistan and Iran a third interrupted mountain chain has been discovered beneath the sea; this seems to form a part of the Zagros mountain system. To the south-west of the Carlsberg Ridge and running more or less concentrically with it lies the curved ridge of the Seychelles-Mauritius or Mascarene Bank, at the northern end of which lies the Seychelles Group of islands and at the southern end the islands of Réunion and Mauritius; along the line of the bank is a series of reefs, namely Fortune, Saya de Malha and Nazareth Banks, together with Albatross Island and Cargados Carajos Reef. From the region of Saya de Malha Bank a somewhat lower submarine ridge arises on the north-east side and curves westward to merge finally with the East African coast. It is thus clear that the Indian Ocean is divided from north to south by a great mountain range into eastern and western sections, while subsidiary ridges further subdivide each area into smaller basins.

Geology of the sea floor

At the present time we know extremely little regarding the nature of the rocks of the sea-bottom. The abrupt cessation of the Deccan Trap along the west coast of India clearly indicates that this basaltic outflow must have extended far to the west of the present coast line; it was therefore of special interest to obtain samples of rock of a basaltic character both from the Carlsberg Ridge itself, in Lat. 1° 25′ 54″ N.; Long. 66° 36′ 12″ E. from a depth of some 3,385 metres and again from the deeper area of the Arabian basin, in Lat. 6° 55′ 18″ N.; Long. 67° 11′ 18″ E., from a depth of about 4,850 metres. A careful examination of the chemical and physical characters of these fragments showed, however, that they differ from the Deccan Trap, and indeed from all known sub-aerial basalts, in having considerably less iron in their composition and also in being much less radioactive. Hence they cannot be regarded as a

submarine continuation of the Deccan outflow. It seems probable that the Carlsberg Ridge and its continuation, the Mid-Indian Ridge, are of volcanic origin throughout their whole length, for where the ridge reaches the surface, as at Rodriguez or the islands at the southern end, the rock is in every case volcanic. The same origin accounts for part at least of the Seychelles-Mauritius Bank for, although the Seychelles at the northern end are largely composed of granite, there is some basalt as well and the southern islands of Mauritius and Réunion are definitely volcanic in origin. So also is the basis on which Providence Reef is situated.

Unfortunately we have as yet no conclusive evidence of the age of this great mountain system ; but the age of Providence Reef has been shown to be Tertiary, while the islands at the southern end of the Mid-Indian Ridge, namely Kerguelen, New Amsterdam, St. Paul, Heard and Macdonald, are also all of Tertiary age. If, as seems possible, the Murray Ridge is a continuation of the Kirthar Range of Sind, then this too is of Tertiary age. In this connection it is interesting to note that the line of the Murray and Carlsberg Ridges together forms an exact counterpart of the line taken by the great Rift Valley system of Africa, the two forming a looking-glass reflection of each other on either side of the meridian 55° E. ; both systems, the Rift Valley and the Carlsberg Ridge, are, further, areas of earthquake intensity, a linear belt of secondary intensity passing along each ; such a similarity suggests that the two systems are part of one orographic movement and, if this be so, then there is no doubt that the northern extension of the great Mid-Indian Ridge must be of Tertiary age.

Geologists have reached the conclusion that the long straight line of the west coast of India is the result of an extensive scarp-faulting that occurred at some period after the outflow of the Deccan Trap, for only so can the abrupt cessation of this deposit, which reaches a thickness of some 9,000 feet on the Bombay coast, be accounted for ; the age of the Trap is generally stated to be about the close of the Cretaceous, though it may have continued on into the Eocene, and the west coast of India is supposed to have assumed its present form probably in the Pleistocene period. Blanford has further suggested that a similar fault is to be found running from east to west along the coast of Makran and Baluchistan, and the presence of a submerged part of the Zagros Mountain system seems to corroborate this. The whole of the south-eastern coast of Arabia, from Ras Fartak eastwards past the Kuria Muria Islands almost as far as Ras al Hadd, for the most part terminates in steep or nearly vertical cliffs of stratified sandstone and limestone that may reach a height of 400–600 feet and that clearly, from the horizontal position of the strata, must have been deposited under water ; here the continental shelf is narrow and drops very irregularly into deep water. As the sandstone must originally have extended very considerably further towards the south or south-east, it seems highly

probable that the straight line of the Arabian East African coast is, like that of India, due to an extensive scarp-faulting. If these views be correct, then the whole of the northern part of the Arabian Sea is surrounded by a system of faults and, in conjunction with this there is, at the least, an apparent continuity of the land and submarine mountain ranges; the deep gulley of the Murray Ridge system may perhaps be itself a line of faulting or alternatively may be the now drowned continuation of the old tertiary bed of the Indus River or of its hypothetical precursor the Siwalik or Indo-Brahm River of Pascoe and Pilgrim. All this strongly suggests that at one time, possibly in the Miocene Era, a large area of land occupied this corner of the Indian Ocean but that this has subsequently been fractured off and has subsided to the level of the sea bottom, some 3,300 metres below the surface. The age of the deposits along this stretch of the coast that have been broken across range from Oligocene to early Pleistocene, so that it seems probable that this subsidence, if it be a fact, also occurred in the late Pleistocene Epoch and was thus contemporaneous with the faulting down the west coast of India. In most places along the continental margin the submarine rocks are covered with a thick deposit of terrigenous mud and it is but rarely that actual rock masses are brought up in the trawl or dredge. Up to the present time no specimens have been obtained along the west coast of India, but in the Gulf of Oman several rock fragments were obtained off Muscat from a depth of 274 metres in Lat. 23° 41′ 48″ N.; Long. 58° 36′ E., and these seem to agree in their general character with the rock of the mainland. Off the Kuria Muria Islands between ½ and 1 ton of angular fragments of granite were taken in the dredge from 1,415 metres depth and these seem to have formed part of a scree slope, that is in all probability a submarine continuation of the granite scree slope of the western end of the island Jezirat Hallaniya and the adjoining Soda Island. Fragments of a very similar granite were also obtained from a reef on the continental shelf to the east of Ras Madraka (Lat. 19° 22′ 36″ N.; Long. 59° 52′ E.). Thus along this stretch of coast, where we have reason to believe there is a great scarp fault, the submarine rocks appear to agree with those of the land, as of course they should if such a view is correct.

Changes of sea level

Up to a few years ago practically all changes in the relative levels of sea and land were attributed to movements of the latter, but within recent years it has become recognized that sea-level is by no means a fixed plane and that there have been in the past wide oscillations and movements during which the sea-level has fallen and risen again. From the Oceanographic point of view perhaps the most important movement was that which, according to the view put forward by Daly and others, occurred during the last Glacial Period. At this time the sea-level became markedly

lowered, partly by the actual abstraction from the ocean of large quantities of water, that were locked up in the Polar regions in the form of ice, and partly by the mass attraction of these large ice masses that drew a further quantity of water away from the tropical regions towards the poles. The sum of these two factors caused a fall in sea-level throughout the tropical belt that Daly conservatively estimated at some 60–70 metres, but recently another American, Shepard, in order to account for the presence of deep submarine gulleys off the mouths of many of the great rivers in all continents, has put this fall at as much as 915 metres, his argument being that these submarine gulleys are a part of the old river bed and must have been cut by the rivers when the sea-level was at a correspondingly lower plane.

Submarine gulleys

At least two such submarine gulleys are found round the coasts of India. On the west side, opposite the present mouths of the Indus river, lies the Indus 'Swatch' that cuts through the edge of continental shelf, commencing at a depth of about 30 metres and at its mouth reaching a depth of about 1,134 metres, on each side of which the walls of the gulley rise up to a depth of only 200 metres. At the head of the Bay of Bengal a similar deep gulley, known as the 'Swatch of no ground', lies off the mouths of the Ganges; here too the gulley commences at a depth of about 30 metres and cuts through the edge of the continental shelf, having a depth of about 1,100 metres at its mouth. There is some evidence that yet a third submarine gulley exists off the mouths of the Irrawaddi river in the Andaman Sea. The theory that these submarine gulleys are submerged river-beds rests on the assumption that the continental shelf is an original part of the continent, a view that is by no means universally accepted. An alternative view holds that they are due to the deposition of mud and silt, brought down by the rivers, along the two sides of the outflowing river water, the deposition along the line of the flow being prevented by the corresponding inflowing current of sea-water below the river outflow. The natural course of such an outflowing surface-current of fresh water must depend very largely on the direction of the prevailing wind and in the Indian region this, during the north-east monsoon, is, as the name implies, from that point of the compass, and it is interesting and suggestive to note that in each case this is the direction taken by the submarine gulley, which runs from NE. towards the SW.

Coral reefs

During the Glacial Period, when the sea-level was certainly lower than it is to-day, many banks and islands must have been eroded and cut down by wave action or by sub-aerial erosion. With the subsequent return of a warmer climate and the consequent melting of the great ice caps, the sea-level once again rose and submerged these banks: simultaneously the temperature of the sea became warmer, so

that corals, particularly reef-forming corals, and the calcareous Algæ, Corallinaceæ, etc. were again able to flourish and the eroded banks formed a suitable base on which they could settle and build up reefs and atolls, the height of the reef keeping pace with the steady rise in the water-level. Certain areas seem to have been particularly favourable for such development and in the Laccadive, Maldive and Chagos Archipelagoes were formed extensive reefs, many of which show a typical atoll formation.

In other regions, such as around Southern India and Ceylon, along the coast of Southern Burma, including the Mergui Archipelago, and on round Socotra, Java and the islands of the Malay Archipelago to Australia, we find extensive fringing reefs; similarly along part of the East African coast and up the length of the Red Sea there is extensive reef formation. Around the Andaman and Nicobar islands in the eastern part of the Indian Ocean and fringing Zanzibar and Pemba islands, the Seychelles, Madagascar, Mauritius, Réunion and other islands in the western part are other reefs; while crowning suitable bases we find numerous isolated reefs such as Cargados Carajos, Fortune, Saya de Malha and Nazareth Banks, together with a few isolated atolls such as Farquharson and Aldabra in the west and Cocos-Keeling in the east. Coral growth is thus clearly widespread throughout the Indian Ocean but there are certain regions in which it is conspicuous by its absence. In certain regions, such as around the Bay of Bengal, the reason for this appears to be the adverse effect of the mud and silt that is carried down by the great rivers and is poured into the sea along the continental shelf, smothering and killing off any coral organism that may have found its way there; but in the region of the East African coast to the south of Cape Guardafui and along the south-east Arabian coast such an explanation cannot hold good and it seems probable that in these latter areas the absence of coral is to be attributed to a seasonal upwelling of deep and cold water brought about by the wind of the south-west monsoon.

The fall of sea-level in the last Glacial Period seems to have had a particularly marked effect on the region of the Malay Archipelago. Prior to this epoch a large area of dry land extended to the south-east and included what are now the islands of Sumatra, Java and Borneo, all of which were connected together and formed a part of the Asiatic continent. A little further to the south-east a second large area of land extended northwards from the Australian continent and connected Australia with the island of New Guinea. During the lowering of the sea-level, much of these two areas became eroded and peneplaned, and when at the close of the epoch the sea-level again rose this peneplaned area became drowned, thus causing the separation of the various islands and giving rise to the extensive shelf areas that exist at the present day. This drowning

of the Malayan area must have very greatly increased the connection between the Indian and Pacific Oceans.

Still later and probably not more than some 4,000 years ago a second, though smaller, fall of sea-level occurred throughout the tropical belt of all the great oceans, possibly as a result of an accumulation of ice in the Antarctic continent. On this occasion the sea-level fell by only about 7 metres and the result can be seen clearly around the continental coasts in the form of 'raised' sea beaches and wave-worn 'benches' in the cliffs; but the most important result of this fall from the point of view of the Oceanographer was the effect that it had on the coral reefs. Coral can only grow up to sea-level and the fall of this level brought the topmost parts of the reefs above water and thus gave rise to the islands, composed of coral rock, that are to be found at the present day dotted over the reefs or around the rim of the lagoons. In each atoll there was originally, in all probability, a nearly continuous rim of 'land', only interrupted in places by the deep channels that ran from the open sea through the reef into the lagoon; but during the subsequent years wave-erosion and sub-aerial weathering have destroyed much of the rim, and at the present day only a few islands remain, situated usually on the least exposed parts of the reefs, and these too appear to be undergoing gradual destruction, so that after a few more centuries the reefs will in all probability have been completely eroded down to sea-level again and there will then be no islands to mark the position of the coral reefs.

Bottom Deposits.

At the present time we still know practically nothing of the character of the rocks that form the floor of the Indian Ocean. Overlying these rocks are the muds and oozes that have been gradually deposited ever since the ocean first came into existence. These deposits are derived from several sources, namely :—

(i) Water-borne detritus and mud brought down by rivers and poured into the ocean—the result of land-erosion;

(ii) The products of marine erosion on the coasts and the breaking up by wave action of the continental margin, as well as the remains of animal and plant organisms, such as shells, corals, calcareous algæ (*Halimeda*), etc., thus giving rise to marine muds;

(iii) Volcanic lava and ash thrown up by submarine volcanoes.

(iv) Air-borne dust and cosmic particles of extra-terrestrial origin; and lastly

(v) The remains of pelagic and other marine organisms, such as Diatoms, Foraminifera, Radiolaria, Pteropoda, etc., which build up from the chemical constituents

of the water, shells or skeletons that, when the animal dies, sink to the bottom and form a varying proportion of the mud or ooze.

It is the varying proportion of these constituents that give to the deposit its characteristic appearance and composition; thus round the coasts and forming at least a large part of the Continental shelf we find terrigenous muds: but, as we pass away from land into greater depths of water, the remains of pelagic organisms, especially those of animals that have a calcareous shell, begin to preponderate and in these regions the sea-floor is usually covered with Globigerina ooze, or where the shells of the pelagic molluscs, the Pteropoda, predominate, with Pteropod ooze. In still greater depths the action of the sea-water dissolves these calcareous remains before they are able to reach the bottom, but the siliceous remains of other pelagic organisms are unaffected and we thus get a type of deposit in which the skeletons of pelagic Radiolaria predominate, and to this type the name Radiolarian ooze has been given, or else, as for instance around the South Polar region, the characteristic feature of the deposit is the remains of Diatoms, and hence here we get a Diatom ooze. Finally, where Foraminifera, Radiolaria or Diatomacea form but a small part of the deposit and the main bulk is derived from air-borne dust and cosmic particles or perhaps from volcanic debris or very fine terrigenous mud, we get the type of deposit that is termed Red Clay.

Terrigenous mud

Associated with the presence of numerous rivers opening into the Bay of Bengal and Andaman Sea we find, as one would expect, that much of the sea-floor is covered with terrigenous muds, and as a result of this continual deposition it has been estimated that the sea-ward edge of the Continental shelf at the head of the Bay is steadily moving southwards at a rate of one mile in forty years. As we approach the mouth of the Bay this mud gives place to Globigerina ooze with which in the central area is mixed a number of masses of water-logged pumice, that in all probability was largely derived from the great explosion of Krakatoa in 1883 and after drifting up into the Bay became water-logged and sank, being slowly swept by the rotatory movement of the deep water in the Bay inwards towards the centre of the region.

Similarly at the head of the Arabian Sea, where the outflowing water from the Persian Gulf sweeps along the detritus from the Tigris and Euphrates rivers, and off the coast of India where the Indus and Narbadda rivers pour their silt-laden waters, the sea-floor is covered with a green terrigenous mud, that in the deeper levels of the Gulf of Oman gradually changes to a grey mud or clay. Under the influence of the north-east winds a great deal of this mud seems to be swept by the current along the coast of Arabia and even into the Gulf of Aden.

Pteropod ooze

In the Red Sea the bottom deposit is of a different type in the northern and southern areas; in the northern part the deposit is a yellow mud, whereas in the southern region the colour changes to brown and here the inflowing current from the Gulf of Aden carries in large numbers of Pteropoda, which are killed off in thousands by the sudden change in the character of the water, and their shells, falling to the bottom, give rise to a Pteropod ooze, in which a calcareous rock appears to be in process of formation. Patches of Pteropod ooze are also to be found in the Andaman Sea and on the floor of the 'Swatch of no ground' off the delta of the Ganges.

Azoic area

Along the eastern part of the South Arabian coast and in the Gulf of Oman a large area of the sea-bottom appears to be markedly inimical to animal life for between the depths of approximately 200 and 1,250 metres the whole of the region comprises a large azoic area and this condition reaches its height off Ras al Hadd where the bottom mud is strongly impregnated with Sulphuretted Hydrogen gas, the source of which is at present unknown. Small quantities of the same gas are to be found in the muds of some of the Maldive Atolls and in a few other localities, as off Bombay and off the Arabian coast near Aden.

Globigerina ooze

In the deeper waters of the Indian Ocean the bottom deposit changes from terrigenous mud, or in the neighbourhood of the great coral reefs from coral mud, to Globigerina ooze.

Red Clay

In the deepest areas of all and especially in the Arabian Basin to the north-east of the Carlsberg Ridge, the Indo-Australian Basin in the south-east part of the ocean between the Mid-Indian Ridge on the west and the Malay arc and Australia on the east, and in the South-Australian Basin the floor is covered with Red Clay, and a patch of this deposit is also found in the Madagascar Basin.

There is very little Radiolarian ooze in the Indian Ocean but patches of this deposit have been found in the Indo-Australian Basin to the north of Cocos-Keeling Atoll, in the South Somali Basin, where it seems to be surrounded by a small patch of Red Clay, and in the Mascarene Basin.

Diatom ooze

In the southern area, from about Lat. 45°–50° S., the bottom deposit consists of Diatom ooze, a type of deposit that is characteristic of Polar regions and is associated with the great prevalence of Diatoms in the sea-water of these high latitudes; it is extremely interesting to note how closely the northern limit of this deposit coincides with the line of the Sub-polar convergence, where the cold polar water meets and is driven below the water of the West-wind Drift.

HYDROGRAPHY. (Figure 2).

The Indian Ocean is filled with water that can be divided, as we pass from the surface to the bottom, into a succession of strata, each characterized by the temperature and salinity of the water, as well as by the amount of oxygen that is dissolved in it. Each stratum is in a state of continual movement, the direction of flow being determined by external forces, such as the winds and the spin of the earth, and by an internal factor, the density. Recent work has indicated that there are at least four and possibly five such strata.

Surface stratum

At the surface and extending downwards for some 100 metres is a stratum of water that is continually moving from place to place under the combined influence of the wind and the spin of the earth, while its composition varies from area to area and from season to season according to the degree of evaporation, that raises the salinity, or the amount of rainfall, that lowers the salinity either directly by oceanic storms or indirectly by the outflow of river water and in Polar regions by the amount of melting of the ice. The extent to which rainfall will influence the salinity of the sea-water varies again from region to region, according to the number and size of the rivers that empty into it. Such a lowering of salinity is very marked on the east side of India, since opening into the Bay of Bengal there are no less than six large rivers, namely, the Cauvery, Kistna, Godavery, Mahanaddi, Ganges and Brahmaputra, as well as innumerable smaller streams, while further east and opening into the Andaman Sea are the Irrawaddi, Sittang, Salween and Tenasserim rivers. On the west side of India the only rivers worthy of note that flow directly into the Arabian Sea are the Indus, Narbadda and Tapti. As a result the surface water of the Bay of Bengal has a lower salinity than that of the Arabian Sea and this is particularly the case during the months that follow the rainy season of the south-west monsoon.

Surface currents

In the Tropical and Sub-tropical region of the Indian Ocean the surface water is driven along by the south-east trade winds in the southern hemisphere and by the alternating north-east and south-west monsoon winds in the northern hemisphere, so that during the winter months the bulk of the surface water tends to converge on the African coast. In the neighbourhood of the north end of Madagascar the westerly-flowing current divides into two streams, one of which turns north to form the Somali stream, that is very weak at this time of the year but which forms a very strong current during the south-west monsoon, while the other bends to the south and, passing between Africa and Madagascar, is reinforced by a further part of the south-equatorial current that sweeps round the southern end of Madagascar. These two masses of water

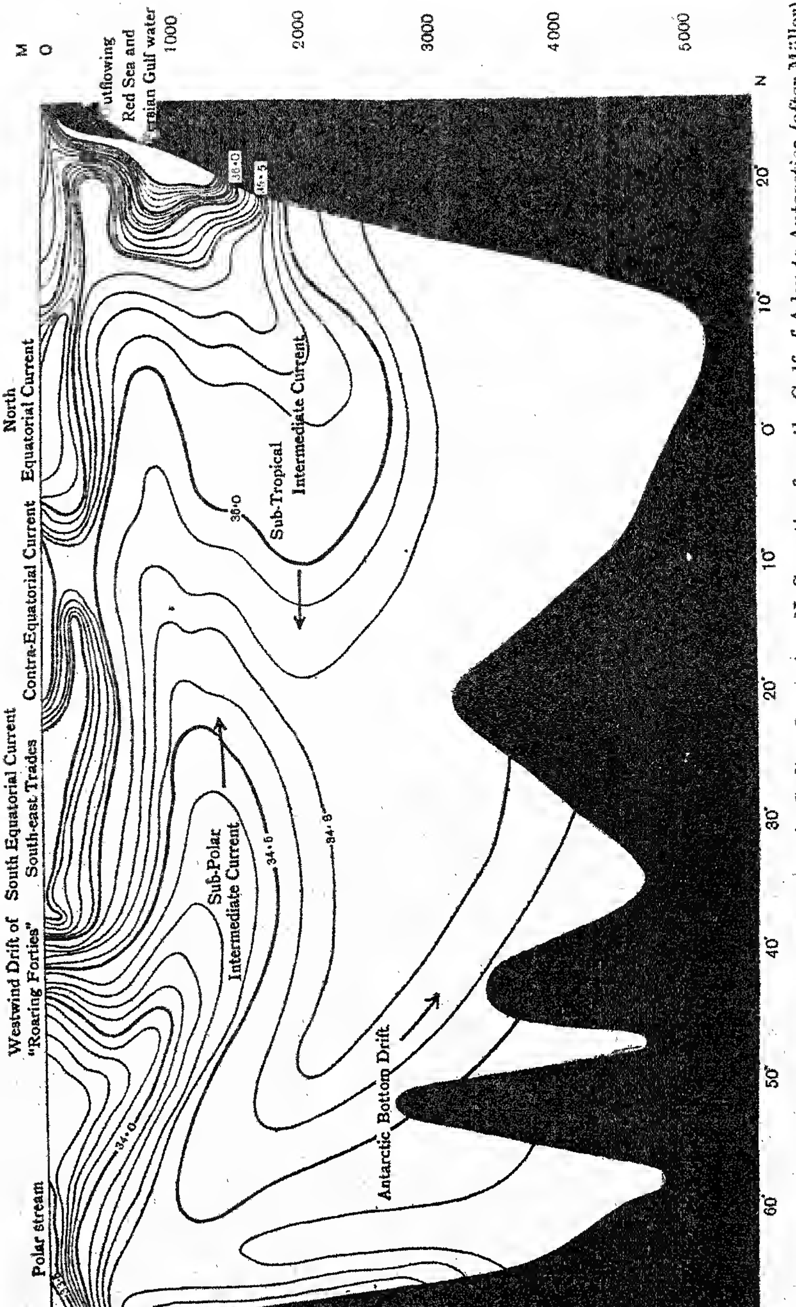
combine to form the great Agulhas current, part of which flows round the Cape of Good Hope into the Atlantic and joins the Benguela current and the south-east Trades of that ocean and the rest swings to the south-east and meets with and joins the West-wind Drift of the 'Roaring Forties'. During the north-east monsoon there is a strong flow of water from the Pacific to the Indian Ocean through the Straits of Malacca into the Andaman Sea and out into the Bay of Bengal, and this, joining with the low salinity Bay of Bengal water, can be traced flowing westwards as far as the Seychelles; during the south-west monsoon this flow from the Pacific to the Indian Ocean is stopped or may be reversed, but there is now a strong flow of water westward between the Malay Archipelago and Australia. In the Equatorial region between Lats. 5° and 10° S. there is a reverse flow of water from west to east, constituting the Contra-equatorial current, that on meeting the less saline surface water of the Bay of Bengal sinks beneath it to join one of the deeper strata.

Tropical Intermediate current

To the west of India the Red Sea opens through the Gulf of Aden into the Arabian Sea on its north-west and the Persian Gulf through the Gulf of Oman on its north side; both of these areas are regions of very little rainfall and high evaporation, and, although the Tigris and Euphrates rivers open into the Persian Gulf, the high evaporation more than counterbalances the influx of river water, so that the outflowing water from these areas has a high salinity and high temperature. As this water flows seaward it becomes cooler and, as a result of the consequent increase in density, sinks below the surface and forms one of the deeper water strata; this stratum is known as the Tropical Intermediate current, and as it passes southwards is in all probability joined opposite the southern end of India and Ceylon by a mass of water that has sunk down beneath the surface in the Bay of Bengal and that on leaving the Bay seems to swing towards the west or south-west. This combined mass of water passes across the Equator at a depth of about 1,000 metres and appears to swing towards the south-east, sinking as it goes, so that in Lats. 40°–50° S. it lies at between 2,000 and 3,000 metres depth; further south than this it tends to rise again towards the surface.

Sub-polar Intermediate current

In the southern area of the Indian Ocean under the influence of the west winds of the 'Roaring Forties' there is set up a circum-polar movement of the surface-water that is continually moving towards the east and north-east; the line along which this sub-polar water meets the water of the South-east Trade Drift is known as the Sub-tropical Convergence line and here the sub-polar water sinks beneath the surface and can be traced flowing towards the north at a depth of about 1,000 metres as far as the Equator or even beyond, for ultimately some of this Sub-polar Intermediate current,



TEXT-FIG. 2.—The Circulation of the Water Masses in the Indian Ocean in a N.-S. section from the Gulf of Aden to Antarctica (after Möller).

as it is termed, can be traced as far as the Gulf of Aden and the Gulf of Oman. To the south of the 'Roaring Forties' and between this and the Antarctic continent the surface Polar water is continually moving towards the north-east; owing to its greater density this water is driven below the Sub-polar water, forming the Sub-polar convergence or 'Meinardius Line.'

Antarctic Bottom Drift

Finally in the deepest levels of all we find a mass of water of low salinity and low temperature that is coming from the South Polar region and is moving, along the bottom at first towards the north-east and then to the north, up into the Indian Ocean and on past the Equator into the Arabian Sea and the Bay of Bengal, forming what is known as the Antarctic Bottom Drift. Owing to its situation on the bottom this deep layer is particularly influenced by the bottom topography; submarine mountain chains or the trend of the continental coast-lines will largely determine the direction of flow and we thus find that the Mid-Indian Ridge splits this Drift into two great streams; the one to the west of the Ridge passes northwards till it comes in contact with the Mauritius-Seychelles bank, which splits it into two streams that pass respectively to the east and west of this curved mountain chain into the North and South Somali Basins. The western stream flows towards the north-west, probably turned in this direction by the curve of the Mauritius-Seychelles bank, till it meets the African coast, where it is deflected towards the north-east and, finally, passing Cape Guardafui and Socotra flows in part into the Gulf of Aden, while the last traces of it run parallel to the Arabian coast and so enter the Gulf of Oman. The eastern branch appears to be in the main deflected upwards towards the surface, where it may serve to augment the mass of water that is flowing eastwards in the Contra-equatorial current. East of the Mid-Indian Ridge between the Kerguelen Plateau and Australia the second great stream of Antarctic Bottom Water flows north-eastwards and meeting the curve of the Malayan arc swings northwards to the entrance of the Bay of Bengal, where, meeting Carpenter's Ridge, it too is split into two streams, one passing on into the Bay along its east side and the other sweeping westward across the mouth of the Bay till it reaches the east side of Ceylon and South India and is again split into two streams, one branch passing up the east side of India into the Bay of Bengal and the other passing further westwards into the Laccadive Sea and possibly across the Maldive Ridge into the Arabian Basin. As a result of the two streams passing into the Bay of Bengal along its two sides, a complicated rotary movement of the water masses is set up on the bottom and this has resulted in floating objects such as pieces of pumice, that gradually become water-logged and sink, being slowly swept round and round till they finally come to rest on the bottom in the central region of the Bay.

In addition to these movements of water within the Indian Ocean there is evidence to show that a continual exchange of deep water is going on between the Indian and both the adjacent oceans, the Atlantic and Pacific. On the south-west side of the Indian Ocean at a depth of about 2,000–4,000 metres there seems to be a deep current of water, having a low salinity but a high oxygen content, coming out of the Atlantic Ocean and flowing eastward past the Cape of Good Hope into the Indian Ocean and then northwards up the east coast of Africa as far as Madagascar. A similar deep current probably passes to the south of Australia between the Indian and Pacific Oceans.

Seiches

In addition to these currents and drifts in the deep waters of the Indian Ocean there is some evidence that seems to indicate that the deep water is, at least in certain seasons of the year, undergoing a periodic to-and-fro swing or 'seiche' in some of the more or less enclosed areas. Up to the present time such evidence is available only for the Bay of Bengal and the Andaman Sea; and it is especially in these two regions that the inflowing river water causes, as we have seen, a lowering of the salinity of the surface stratum, so that a layer of less saline water rests on a deeper more saline stratum. During each monsoon the surface stratum under the influence of a more or less constant wind, blowing from the north-east or south-west according to the season, is driven towards one side of the region and is there piled up against the coast line so that this surface layer becomes thicker on that side of the area than on the other and the plane of demarcation between the two layers becomes inclined; with the cessation of the impelling wind at the close of each monsoon this plane of demarcation immediately tends to return to the horizontal and in consequence there is developed in the bottom stratum a swing of the water that has a time period depending on the depth and density of the two strata and the size and shape of the containing basin. As a result of this to-and-fro swing the deeper stratum will periodically and alternately at each end of the basin be brought nearer to the surface and at such times under the influence of wave-action there will result a certain degree of mixing between the upper and lower strata, so that the salinity of the coastal water will exhibit a rise and fall showing the same periodicity. No actual proof of such a swinging movement in the deeper water has as yet been obtained in these two regions but it has been found that the surface salinity of the coastal waters of both the Bay of Bengal and the Andaman Sea exhibit a rhythmic rise and fall, the period of which corresponds exactly with the time that a seiche should take in these waters, namely, in the Andaman Sea, where the seiche would appear to be of the uni-nodal type if it be present, from 17–19 days and in the Bay of Bengal, where the seiche would seem to belong to the bi-nodal type, of 15·5 days in the long axis of the Bay and of some 5·5—6 days in the transverse axis.

Associated with this periodic variation in the salinity of the surface water there may be at certain seasons an equally periodic appearance in the upper levels of large numbers of animals, such as small Salps, Rhizostomous Medusæ or certain species of pelagic Crustacea, that, in all probability, normally inhabit a deeper stratum but are carried up towards the surface by the upward swing of the deeper water.

Oxygen content

From the point of view of the marine Biologist one of the most important ingredients of the sea-water is the oxygen that is contained in solution. This oxygen is derived from the surface, partly by direct solution from the atmosphere in the uppermost water layer and partly by the action of the chlorophyl-bearing phyto-plankton, that under the influence of direct sunlight carries out the process of photo-synthesis, building up certain simple chemicals, such as nitrates and phosphates, into their body tissues and setting free oxygen that is at once dissolved in the water; clearly this process can only be carried out in the extreme upper levels, since the depth to which light can penetrate the sea-water is very limited and, where there is a large amount of plankton in suspension, this depth will be even smaller than usual. Correlated with this we find that whereas there is a fair supply of oxygen in the upper levels, this rapidly diminishes as we pass downwards, the oxygen being used up by the zoo-plankton and other pelagic animals, till at a depth of about 100 metres there is usually less than 1·0 cc. of oxygen in a litre of water and at 800–1,000 metres depth less than 0·1 cc. Passing still further downwards towards the bottom we find that the amount of dissolved oxygen again begins to increase till in the deepest depths the amount present may be as much as 2·5–2·75 cc. per litre; this increase in the bottom levels is correlated with the sinking of the South Polar water from the surface to give rise to the Antarctic Bottom Drift, that carries a supply of oxygen along the bottom of the ocean up to and beyond the Equator.

Nutrient salts

As the nitrates and phosphates in the surface waters are built up into the tissues of the plants and subsequently, after digestion, into the bodies of the animals that feed on the plants, the supply of these salts at the surface will gradually be depleted, whereas, as the animals and plants die and their carcases sink to the bottom, where by bacterial or some similar action the nitrates and phosphates are again set free, the bottom water will gradually become more and more rich in these salts. The replenishment of the surface and upper levels can thus only be brought about by an upwelling of bottom water towards the surface. Such upwelling is known to occur along the east coast of Africa near Cape Guardafui and along the south-east coast of Arabia during the south-west monsoon, for the study of hydrodynamics has shown that under the influence of a strong wind the water of the sea-surface is swept in the northern hemisphere,

not in the direction in which the wind is blowing but at an angle to the right of this, so that the south-west monsoon wind, which blows more or less parallel to these coasts, will drive the water away from the land and thus cause deep water to well up to the surface to take its place; a similar upwelling of water appears to take place on the east of the Seychelles-Mauritius bank, where it serves to augment and to replenish the supply of nutrient salts of the Contra-equatorial current. In consequence of this replenishment of the nutrient salts in these two areas we find that the amount of plankton present in the upper levels is particularly rich. In addition to this supply of nitrates from the bottom water a further source of supply is in all probability to be found in the Tropics in the rainfall, and especially that which occurs during thunder-storms. During such storms the electrical discharge in the lightning causes the formation of nitric acid and this is carried down in the rain; it has been estimated that as much as 5 tons of this acid is formed annually over every square mile of India. Much of this acid becomes combined with alkalies in the soil and thus serves to fertilize the land but, in addition to the amount that falls directly into the sea, a great deal must also be carried into the great rivers and eventually be poured into the sea, especially in the Bay of Bengal and the Andaman Sea, into which so many of the rivers of India and Burma open; during the north-east monsoon the water is swept out of the Bay of Bengal and round the south of Ceylon westwards and can be traced extending on the surface in a wide belt as far as the Seychelles, and during the John Murray Expedition the surface water in the neighbourhood of the Maldive Archipelago in February was found to be particularly rich in nitrates, that may thus be accounted for.

Mineral salts

Along with the supply of nutrient salts the large rivers carry down a supply of mineral salts that are beneficial to the growth of Diatoms and it has been found that estuarine regions are particularly rich in phyto-plankton, whereas, as we proceed further and further towards the open ocean, the character of the plankton changes and becomes zoo-planktonic in character. Usually in the open waters of the tropical ocean the amount of zoo-plankton present at any given time is comparatively small, as compared with that in more northern or southern regions; this has been used as an argument in support of the view that tropical waters are relatively deficient in animal life as compared with the cooler, more northerly or southerly regions; but it must be borne in mind that the rate of reproduction in the Tropics is considerably more rapid than in colder climates and moreover in all probability the breeding season is much more prolonged, so that there is not so great a degree of disparity, if indeed there be any, in the total amount of life in the ocean between Tropical and Sub-tropical or Polar regions.

In spite of the fact that plankton of the zoo- and phyto-types appears to have, at any rate in certain areas, a mutually exclusive action on one another, so that where phyto-plankton is particularly abundant the number of animals present is comparatively small, there is no doubt that the amount of zoo-plankton than can exist in any area of water depends on the amount of phyto-plankton on which the animals can feed, whereas on the other hand an increase in the number of herbivorous animals will cause a fall in the amount of plant life. It has been found in Indian waters, as in the more northerly waters of the North Atlantic, that there is annually an increase in the amount of phyto-plankton present in the surface waters in the month of April—the spring outburst—at the time of year when in Indian waters the sea-water is warmest and when there is plenty of sunlight. A month or two later, however, this burst of plant life is succeeded by a marked increase in the amount of the zoo-plankton and simultaneously the quantity of the phyto-plankton becomes reduced.

Biology.

Since the vast majority of marine animals at some stage or other of their existence pass through a floating or pelagic stage, during which they form a part of the plankton that is swept along by the currents and so drifts from place to place in the ocean, a study of the movements of the water masses is of the greatest importance for the right understanding of their distribution, not only because this movement provides the necessary mechanical propulsion but because within the limits of such currents the water maintains, with only very slight and gradual changes, a more or less constant physico-chemical condition that is required by the organisms inhabiting it, any rapid change of either salinity or temperature being almost invariably fatal.

Many of the planktonic animals are capable of a certain degree of independent movement by which they are able to adjust their level in the ocean ; thus certain organisms may be found at or near the surface at night, but at the approach of dawn and the onset of brilliant light, which they almost universally dislike, they swim downwards through a comparatively short distance and so reach a level where the intensity of the light is best suited to their existence ; as the day closes they once again move upwards and make their appearance on the surface. Such a vertical migration may be assisted by the daily change-over of the upper water levels, that is brought about by the daily change in salinity. During the day the uppermost stratum of the water becomes, as a result of evaporation, more saline, though owing to warming by the sun's rays it is rendered less dense and so remains at the surface ; with the onset of night and consequent cooling this surface water becomes more dense and sinks to a deeper level, being replaced at the surface by

water which wells up from below and this daily 'change-over' in the upper stratum must to some extent carry the plankton with it, so that an organism that swims downwards to a deeper level during the early part of the day may again be swept towards the surface at night. Such a vertical migration will, however, have but little effect on the horizontal movement and thus the distribution of the plankton over such a wide area as the Indian Ocean must in the main depend on the strength and direction of the various currents at all depths and thus these will to a large extent influence and determine the general character of the fauna in any given region.

As we have seen, there is, owing to the general trend of the surface currents and especially during the north-east monsoon, a transference of large masses of water from the Pacific Ocean through the Malay Archipelago to the Indian Ocean: on the other side, however, but little of the surface water of the Indian Ocean passes westward round the Cape of Good Hope into the Atlantic Ocean, and that which does so comes into contact and becomes intimately mixed with a cold current, the Benguela current, that is derived partly from the Sub-polar region and partly by upwelling from below off the south-west coast of Africa. The consequent fall of temperature in the surface water would be extremely harmful to any pelagic organisms that might have been swept round from the Tropical or Sub-tropical regions of the Indian Ocean and few would manage to survive it. Thus, while there is a close connection faunistically between the upper levels of the Indian and Pacific Oceans—the two together forming a vast Indo-Pacific region—, the Atlantic Ocean has developed a fauna that is more or less characteristic of that area; but even so, a number of littoral weed-haunting forms, such as the Harpacticid Copepoda, appear to have been able to make their way westward, and, following the currents of the Atlantic, have reached the east coast of North America, for no less than 30% of the known Indian Harpacticids have been found on the shores of Wood's Hole, Massachusetts and around Bermuda, while, continuing along the North Atlantic Drift and the Gulf Stream, some 16% have reached the coasts of England and about 12% have got as far as Norway.

Within recent years the cutting of the Suez Canal has provided a short cut for organisms to pass from the Indian region through the Red Sea and the canal into the Mediterranean Sea, and already a certain number of animals have made their way from east to west; doubtless with the passing of the years more and more will be able to do so, so that the fauna of the Mediterranean, and especially its eastern basin, may in time to come have a close affinity with that of the Indian Ocean, the extent of the change depending on the degree to which Indian forms can supplant those now living in the Mediterranean.

On the eastern side of the Indian Ocean the free passage of surface water between the Pacific and Indian Oceans has resulted

in the fauna of the Malay Archipelago being at the present time decidedly Pacific in type ; but in the not far distant past there seems to have been a very rich production of new species in the Malayan region and the movement of the water masses has caused the extension westward of this fauna. A large number of these Pacific or Malayan species have been carried or have actively migrated westwards ; many have invaded the Andaman Sea and appear to have been unable to get any further, but numerous others have been able to reach and have established themselves in the great coral-bearing regions of the Chagos, Maldive and Laccadive Archipelagoes, in the Seychelles and around Réunion and Mauritius, and even ultimately have reached the African coast and the Gulf of Aden. In some at least of the various groups of animals it has been found that the further west we proceed, the fewer are the number of Malayan species to be found and, even in those instances where a species has been able to survive and establish itself, the individuals are often smaller and are 'depauperized' as compared with their congeners in the Malayan region. In other cases the change from east to west seems to have been accompanied by a structural change in the organism and in consequence we find that a number of species are peculiar to the Indian region but that their nearest relatives, and those from which they have in all probability been evolved, are to be found in the Malayan Archipelago.

It has recently been discovered that a very high percentage of species of Marine Algæ are common to the Indian Ocean and the North Atlantic Ocean, some even occurring in the Arctic region. The presence of North European species in the Arabian Sea is attributed to a migration from the north-west when an open connection between the two regions existed through the Tethys Sea ; similarly Indo-Pacific species are supposed to have migrated through this sea from the Tropics to the Mediterranean. Similarly, as regards the fauna numerous authors in the past have drawn attention to the large percentage of littoral-haunting species and especially of species from depths ranging from 350 to 1,900 metres that are common to the Indian Ocean and the North Atlantic. Alcock in his report on the Deep-Sea Fishes states that 'if we estimate the number of Indian genera of marine fishes at 350 and of species at 1,200, then over 56 per cent. of the genera and close on 5 per cent. of the species are also found in the Atlantic-Mediterranean region.' The explanation of this degree of similarity is again attributed to the former presence of a direct connection between these two regions through the Tethys Sea. It must, however, be borne in mind that the constant influx of water at some 2,000–3,000 metres depth from the Atlantic Ocean past the Cape of Good Hope into the Indian Ocean, as well as the steady drift of Antarctic polar water, in either the Sub-polar Intermediate current or in the Bottom Drift, up to and even beyond the Equator, provide high ways along which conditions of temperature, salinity and oxygen-content

remain remarkably constant, so that there is little or no barrier to the migration of genera or species that are capable of even a slight degree of adaptation to their surroundings. It thus seems probable that although in some instances the occurrence of the same species in the north Atlantic and the Indian Ocean may be due to the persistence in these two regions of a form that originally in early Tertiary times was continuously distributed through both areas and the intervening Tethys Sea, in other instances their distribution may be due to either active migration or to passive drifting from one ocean to the other along the deep high ways of the ocean currents and the discontinuity of their habitat may be apparent rather than real: but this problem must await a final solution till we know a great deal more about the fauna and flora around the Cape of Good Hope and the east coast of Africa on the one hand and the coasts of Antarctica on the other.

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AN OUTLINE OF THE GEOLOGICAL HISTORY OF INDIA.

By

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CONTENTS.

INTRODUCTION.

The three physical divisions of India

The most outstanding fact about the physical geography and geology of India, which in fact is the resultant effect of its late geological history, is the division of the country into three distinct segments of totally dissimilar characters: (1) The great, flat alluvial plains of Northern India extending from Sind to Assam —the India of legend and history; (2) the Peninsula of the Deccan, south of the Vindhyan mountains, a solid and stable block of the earth's crust, largely composed of some of the most ancient rocks of the earth, which the denudation of ages has carved out into a

number of mountain-ranges, plateaus, valleys and plains; and (3) the great mountain barrier which surrounds the plains to the west, north and east, known as the extra-Peninsula. The following differences summarize the main points of divergence between the last two regions. The first difference is *stratigraphic*, or that connected with the geological history of the areas. Ever since the Cambrian period, the dawn of geological history, the Peninsula has been a land area, a continental segment of the earth's circumference, which, since that epoch, has never been submerged beneath the sea except locally and temporarily. No appreciable marine deposits of a later age than Cambrian have been laid down in the interior of this land-mass. The extra-Peninsula, on the other hand, has been a region which has been underneath the sea for the greater part of its history, and has therefore been covered by successive marine deposits characteristic of all the geological periods commencing with the earliest, the Cambrian.

The stable Peninsula and the folded extra-Peninsula

The second difference pertains to the *geological structure* of the two regions. The Peninsula of India reveals quite a different type of architecture of the earth's crust from that shown by the extra-Peninsula. Peninsular India is a segment of the earth's outer shell that is composed, in great part, of generally horizontally reposing rock-beds that stand firm and immovable upon a stable and resistant foundation and that have remained so for a long cycle of ages, impassive and unfolded amid all the revolutions that have again and again altered the face of the earth. The only structural disturbance it has undergone is of the nature of lines of faults or fractures in the crust, due to tension or compression. The extra-Peninsula, on the contrary, appears to have been a weak and comparatively flexible portion of the earth's circumference that has undergone a great deal of crumpling and folding of the rock-beds indicating repeated upheaval and subsidence under the sea. The third difference between the Deccan and the highlands of Northern India is *physiographical* and arises from the two above-mentioned differences. In the Peninsula the mountains are mostly of the 'relict' type, *i.e.*, they are not true mountains of upheaval, but are mere outstanding portions of the old plateau of the Peninsula that have escaped, for one reason or other, the weathering of ages that has removed the surrounding parts of the land. Its rivers have flat, shallow valleys, with low gradients, because of their channels having approached to the base-level of erosion. Contrasted with these the mountains of the other area are all true mountains, owing their origin to a distinct axial uplift of the rock-beds. The rivers of this area, as a consequence, are rapid, torrential streams, which are still in a youthful or immature stage of river-development and are continuously at work in cutting down the inequalities in their courses and degrading or lowering their channels.

TABLE OF GEOLOGICAL FORMATIONS OF INDIA.

SIONS.	PENINSULA.		EXTRA-PENINSULA.	GEOLOGICAL AGE.
ARYAN ERA	Newer alluvium ; delta deposits ; raised beaches ; blown sand.		Low-level river-terraces : newer moraines : talus-fans.	RECENT
	INDO-GANGETIC ALLUVIUM. Older alluvium of the Narbada, Godavari ; loess ; desert sands of Rajputana and Cutch. Cave-deposits of Karnul.		Upper KAREWAS of Kashmir : Glacial moraines (middle).	PLEISTOCENE
	High-level LATERITE. CUDDALORE SERIES : Perim island conglomerates. Warkalli beds: Quilon beds.		ICE AGE / SIWALIK SYSTEM: Boulder-conglomerate stage. Tatrot stage. Dhok Pathan stage. Chinji stage. Kamlial stage. Irrawaddy system of Burma. Manchar system of Sind.	PLIOCENE
	Mid. Tertiary of Cutch : Dwarka beds.		Upper MURREE SERIES : Kasauli series : Surma series of Assam.	LR. MIOCENE
			GAJ SERIES : Bugti beds : Lower MURREE series : Dagshai series. (Upper Indus Tertiaries.)	
	Nummulitics and Up. Eocene of Gujarat, Kathiawar and Rajputana.		NARI SERIES of Sind, Baluchistan and Cutch. Barail series of Assam. (Upper Indus Tertiaries.)	OLIGOCENE
			KIRTHAR SERIES of Sind and N.W. Punjab : Jaintia series of Assam. (Upper Indus Tertiaries.)	UP. EOCENE
			LAKI SERIES of Sind, Salt Range, Kohat, Pir Panjal and Simla (Subathu series). (Upper Indus Tertiaries.)	LR. EOCENE
	DECCAN TRAPS with fresh-water inter-trappean beds.		RANIKOT SERIES of Sind, Salt Range, Kohat and Outer Himalaya.	
	Marine CRETACEOUS OF S.E. COAST LAMETA SERIES: BAGH BEDS of Narbada valley.	Ariyalur stage. Trichinopoly ,, Utatur ,,	Cardita beaumonti beds of Sind. Cretaceous volcanic series of Burzil and Dras, Kashmir. Cretaceous of Baluchistan (Parh limestone and Pab sandstone) and of Sind. Chikkim series of Contral Himalaya. Giumal series of Spiti, Hazara and Kala Chitta.	CRETACEOUS
	Marine JURASSICS OF CUTCH—*Umia, Katrol, Chari and Patcham* series. UPPER GONDWANA of Jabalpur, Satpura range, Rajmahal hills and Cutch.	Umia series. Rajmahal series. Kota series. Jabalpur series.	SPITI SHALES : Jurassics of Baluchistan. KIOTO LIMESTONE : Lr. JURASSIC of Himalaya, Kala Chitta and Salt Range.	JURASSIC
		Parsora stage ; Maleri series.	Upper and Middle TRIAS OF Spiti and Kashmir. Megalodon limestone.	UP. TRIAS
		Mahadev (Pachmarhi) series. Panchet series.	CERATITE BEDS of Salt Range : Lr. TRIAS of Spiti and Kashmir.	LR. TRIAS
	LOWER GONDWANA with coal-measures of the Damodar, Mahanadi, Godavari valleys and Satpura.	Damuda series.	SIRBAN LIMESTONE of Hazara : Krol series of Simla-Chakrata. PRODUCTUS LIMESTONE of Salt Range : ZEWAN series of Kashmir and Spiti. Conularia beds and Eurydesma zone of Salt Range and Kashmir. (PANJAL VOLCANIC SERIES.)	PERMIAN
		Talchir series (glacial).	GLACIAL BOULDER-BEDS of Salt Range, Hazara and Simla (Blaini series). (PANJAL VOLCANIC SERIES.)	UP. CARBONIFEROU
DRAVIDIAN	[Unrepresented.]		Fenestella series of Kashmir : Po series of Spiti.	MD. CARBONIFEROU
			Syringothyris limestone of Kashmir : Lipak series of Spiti.	LR. CARBONIFEROU
			Muth system of Central Himalaya and Kashmir, Devonian of Chitral.	DEVONIAN
			Lower Tanawal, Jaunsar and Nagthat series (unfossiliferous). Silurian and Ordovician of Central Himalaya and Kashmir.	SILURIAN
			HAIMANTA SYSTEM of Spiti : Mid. and Up. Cambrian of W. Kashmir : Neobolus beds of Salt Range.	CAMBRIAN
PURANA	VINDHYAN SYSTEM : Kurnool series : Malani series : Pakhal series : Bhima series. CUDDAPAH SYSTEM : DELHI SYSTEM : Penganga series.		Dogra slates : Simla slates : Attock slates. Metamorphosed slates, sandstones and conglomerates of the Middle Himalayan Zone.	ALGONKIAN
RCHÆAN (VEDIC)	DHARWARIAN— Most ancient sediments with intrusive granites and gneisses—ARAVALLI SYSTEM of Rajputana : IRON-ORE SERIES : SAUSAR SERIES of C.P. : Bijawar series : Raialo series : Gwalior series. ——Eruptive unconformity Oldest igneous GNEISSES of the Peninsula :—		Highly metamorphosed sediments of the Middle and Inner Himalaya—Vaikrita series of Spiti : Daling series of E. Himalaya : JUTOGH series of Simla and SALKHALA series of Kashmir.	ARCHÆAN

The Indo-Gangetic Plains, a depression

The third division of India, the plains of the Indus and Ganges, though humanly speaking of the highest interest and importance, as being the principal theatre of India's history, and a source of the great agricultural wealth of the country, is geologically speaking the least interesting part of India. In geological history it supplies only the annals of the last year, being composed of very late, sub-Recent alluvial and flood-plain deposits of the rivers of the Indus-Ganges system, borne down from the Himalayas and deposited at their foot. The plains have covered up underneath their deep mantle of clays, sand and silt valuable geological records which might have thrown light on the physical history and relations of the Deccan with the Himalayas. These plains were originally a deep depression, or furrow, which came into existence as a complement of the process of elevation of the Himalayan chain to their north. The filling up of this depression is the work of the latter part of the last geological age—the Pleistocene. The annexed table gives the main outlines of the succession of rock-systems in the different parts of India, arranged in the order of their age and referred to the standard divisions of the geological time-scale accepted for the world.

In the following pages we shall pass in brief review the rock-formations representative of the various geological periods that are found in India; in doing so we shall take into account their chief rock-components, their fossil contents, the geographical revolutions that took place during each age, the effect on the topography and scenery produced by the various systems of rocks and the important economic minerals associated with them.

ARCHÆAN SYSTEM.

The Archæan is the name given to the oldest rock-system of the world, forming the very basement on which all the succeeding systems of the geological column rest. This system is believed by some to represent the first solidified crust of the earth, as it cooled from its original molten condition. The rocks are largely a mixture of gneisses, granites and schists, all thoroughly crystalline and permeated by injection of magma from the deeper, plutonic parts of the crust (orthogneisses and orthoschists). With these crystalline plutonic rocks are associated clastic sediments, which have undergone an extreme degree of metamorphism, due to heat and pressure of the earth's interior, and been converted into foliated crystalline rocks (paragneisses and paraschists). Owing to the conditions under which these rocks were formed and their subjection to mechanical deformations that have taken place in the surface layers of the earth, through the whole vista of geological time, the Archæan rocks have attained an extreme complexity of characters and relations in all parts of the world, which have not yet been

completely unravelled. The Archæan rocks cover three-quarters of a million square miles of the surface of Peninsular India, particularly Madras, Mysore, Orissa, the Central Provinces, Chota Nagpur and Rajputana. They extend north-westwards along the chain of the Aravalli mountains, one of the oldest mountain-ranges of the world, while they build, together with the intrusive granites of later ages, the central, snow-covered ranges of the Himalayas throughout its whole length, forming the very backbone of the mountains. All the high peaks of the Himalaya, from Nanga Parbat in Kashmir to Mt. Everest in Sikkim, are, however, largely composed of granite, which has pierced through this basement complex and is of much later age.

The fundamental gneisses

The great body of crystalline igneous rocks forming the Archæan gneissic complex of the Peninsula, either coarsely crystalline or finely foliated, is broadly classified into several regional units, such as Bengal gneiss, Bundelkhand gneiss, Peninsular gneiss, Charnockites, etc., as shown in the table given above, though no chronological order is implied in this grouping. The prevailing rocks are gneissose granites, charnockites (hypersthene-bearing eruptive rocks from granite to norite in composition), syenites, elæolite-syenites, anorthosites, granulites, calciphyres, calc-gneisses, marbles and hybridised manganese-bearing rocks (kodurite).

The scenery of the picturesque Nilgiri ranges, and of the low, straggling ranges of the Madras coast, the Shevaroys, Anaimalai, Palni hills, etc., is determined by the uneven weathering of the Archæan rocks. The Aravallis owe their deeply worn aspect to the denudation of ages removing the body of the mountains save the outstanding ridges.

Dharwar System.

The Archæan sedimentary rocks

The system of rocks named **Dharwarian** is closely associated with the Archæan gneisses and are probably of the same age. They are however chiefly of sedimentary origin, deposited in the hollows and depressions of the primeval crust, in which the first-formed seas of the world have collected their waters, on the condensation of the vapours that were held till then in the primitive atmosphere. The component rocks are mainly slates, hornblende- and chlorite-schists, quartzites, crystalline limestones and calc-granulites, charged with abundant and wide-spread granite intrusions. The Dharwarian system is best developed in Dharwar, the type area, parts of Mysore State, Rajputana, where it forms the outskirts of the Aravalli chain, in parts of the Central Provinces and Chota Nagpur, and in the belt of metamorphic sediments in the middle Himalayas. The Dharwar rocks of these different provinces illustrate varying characters. In the **Dharwar** district of Bombay,

from which the system takes its name, and in the Mysore State they occur in long narrow bands, the bottoms of compressed synclinals, the intervening anticlinal folds having been worn away. The constituent rocks are hornblende and other schists, slates, quartzites and brilliantly banded cherts. Numerous quartz-veins or reefs traverse these rocks, some of which are auriferous with a gold-content enough to support mining operations. The principal gold-mining centre in India, the Kolar fields of Mysore, is situated on these quartz-reefs.

Rajputana

The **Aravalli system** of Rajputana, consisting of varyingly metamorphosed limestones, phyllites, slates, quartzites and composite gneisses is one vast formation flanking the synclinorium stretching from Delhi to N. Gujarat, whose uplift at the end of the Purana Era has given rise to the most ancient mountain-chain of India. Overlying the Aravallis unconformably there comes another Archæan rock-formation, the **Raialo series,** chiefly marbles. The Archæans of Bihar and Orissa constitute what is known as the **Iron-ore series,** from its containing iron-ore bodies of large dimensions. These rocks are shales, slates and tuffs and banded hæmatite-quartzites containing massive or powdery hæmatite. The petrogenesis of the latter rock is a subject of some controversy. Considerable igneous action prevails, which has given rise to the chromite, asbestos and steatite of Singhbhum. A copper-bearing belt runs along a plane of overthrust in the schists and intrusive granite of Singhbhum. The Iron-ore series is underlaid by a group of crystalline limestones, schists and manganese ore-beds—the **Gangpur series.**

Bihar and Orissa

Central Provinces

The Archæan-Dharwar complex of the Central Provinces is also characterized by a metalliferous facies of deposits rich in ores of manganese. The country-rocks of the districts of Nagpur, Chhindwara and Bhandara are distinguished as the **Sausar series,** consisting of granulites, calciphyres, sillimanite-schists, and hornblende-schists carrying important aggregates of manganese-ores. The Sakoli series of the southern districts, consisting of less altered slates, chlorite-schists and jaspilites, is probably an upward extension of the Sausars. The famous marble-rocks of Jubbulpore as well as the richly manganiferous deposits of rocks, named by Sir L. L. Fermor, the **Gondite** series and the **Kodurite** series, also belong to this system.

Economic importance of Dharwar system

The Dharwar System is of great economic value to India: it carries the principal ore-deposits of the country, chief among which are the ores of gold, manganese, iron, copper, tungsten and lead, the Kolar gold-reefs producing 350,000 ozs. of gold per annum. The 3,000 million tons of high-grade iron-ore reserves of

Orissa, the manganese deposits which have supplied over 17 million tons of manganese-oxide to the world in the last 35 years, the copper and chromium lodes of Singhbhum, are all related to this system. To the same system belong economically useful minerals such as mica, corundum, graphite, and precious and semi-precious stones, *e.g.*, sapphire, ruby, beryl, zircon, spinel. The system is also rich in resources of ornamental marbles; the famous Makrana marbles, used in the masterpieces of Moghul architecture, *e.g.*, those at Delhi and Agra, are a product of the Raialo series.

The Eparchæan Interval.

The rock-formations grouped under the name **Purana group** roughly correspond in age with the Algonkian System of American geologists and succeed the Archæan after a profound regional unconformity. This unconformity is of great significance as it denotes the lapse of a vast interval of time, represented by many cycles of mountain-building and their erosion to the base-level before the lowest beds of the Puranas were deposited. The Purana rocks are a great thickness of pre-Cambrian unfossiliferous slates, quartzites, sandstones and limestones, found principally in the Aravalli chain, the Cuddapah area of Madras, and in the great escarpment of the Vindhya mountains in Central India. The classification of the group is given in the table facing page 45. The Cuddapahs and the Delhis are older and show a greater amount of tectonic plication and deformation than the Vindhyans, which are hardly disturbed from their original horizontal attitudes.

The Cuddapah System.

The type-area of the **Cuddapahs** is the district of this name in the Madras Presidency, where the system consists of 20,000 feet of indurated shales, slates, quartzites and limestones, with bedded lava-flows and tuffs. As in the Dharwars, there occur also brilliantly banded ferruginous jaspers and some manganese-ore. The whole group, though admirably adapted to contain and preserve organic relics, is totally barren of fossils. Workable deposits of barytes and asbestos occur in association with the Papaghni slates and limestones, the lowest member of the Cuddapahs, of the Ceded Districts of Madras.

The Delhi System.

A much higher degree of regional metamorphism and tectonic disturbance is visible in the **Delhi system,** typically exposed in the Aravalli mountains of Rajputana. It overlies the Raialos unconformably and builds the central axial zone of the Aravalli synclinorium, the part of the fold which experienced the most severe compression and depression. The Delhi System occupies a wide extent of Rajputana, extending in constricted, sorely eroded bands

from Delhi to Idar. The constituent rocks, aggregating 17,000 feet in thickness, are slates, phyllites, schists, quartzites, hornstone-breccias, arkoses and crystalline limestones. There is a considerable amount of igneous intrusions in the form of granite bosses and a varied suite of basic rocks. The Gwalior series, like the Bijawar series, which was formerly grouped with the Cuddapahs, is now regarded as homotaxial with the Aravalli, their comparatively lower grade of metamorphism being due to their distance from the axes of orogenic folding in which the Delhis are involved.

The Vindhyan System.

The next succeeding system, the **Vindhyan,** is in most of its area of extension an undisturbed formation, with generally horizontal stratification-planes, resting over the upturned and denuded edges of the underlying rocks. The Vindhyan sediments 14,000 feet in thickness, show two distinct facies of deposits—a lower argillaceous and calcareous (the **Semri series** of the Son Valley area) and an upper, almost exclusively arenaceous, divided into three series, the Kaimur, Rewa and Bhander series, of Central India. The lower Vindhyans show a certain amount of structural displacement and folding and are separated from the upper by an unconformity that is quite apparent in the north but which disappears in the southern areas of Mewar and the Son Valley. Homotaxial in position with the lower Vindhyans is the Malani series of volcanic rocks covering large areas of W. Rajputana. This series consists of partly glassy and devitrified, felsitic or amygdaloidal, rhyolites and quartz-andesites, interstratified with tuffs and volcanic breccias. The Malani series extends far northwards and is observed in some isolated hillocks near Sargodha in the Punjab alluvium. The characteristic Malani rhyolite is distinguished in the boulders occurring in the Upper Carboniferous glacial moraines at the base of the Productus Limestone of the Salt Range, a fact which indicates that the Aravalli mountains were the feeding ground of the glaciers that radiated out to distant parts of India during the Upper Palæozoic Ice Age. Connected with the Malani lava-flows, as their plutonic roots or magma-reservoirs, are the bosses of granite of Jalor and Siwana.

The Malani series

Contemporaneous formations with the Vindhyans are the Kurnool series of Cuddapah, the Bhima series of Southern Maratha country, the Pakhal series of the Godavari Valley and the Penganga beds of the Mahanadi Valley.

Other contemporary series

Life in the Purana Era.

The Cuddapah and Delhi rocks are devoid of all traces of animal or plant life, while the Vindhyan rocks, though so far they have not

yielded any specifically identifiable fossil remains, possess many indirect evidences of the presence of life at the period in fucoid markings, annelid casts and burrows, coaly layers, etc. Primitive life had already appeared on earth, and certain disc-like organisms, occurring in a black shale near Rampura, have been variously referred by different palæontologists to algæ or to valves of primitive brachiopods. In the very next succeeding Cambrian system we come across comparatively highly organized and diversified forms of invertebrates such as crustacea and molluscs, which give clear proof of a long course of antecedent evolution.

The Vindhyan system is of economic importance because of its unlimited resources in building stones of great beauty and durability. The famous 'Golconda' diamonds, for which India was once a much-sought market, were derived from some conglomeratic beds in the Upper Vindhyans, the original source of the diamond being probably certain basic dykes in the Cuddapahs or Bijawars.

The isolated mountain masses designated the Eastern Ghats, are composed of Archæan and Cuddapah rocks, while the series of steep escarpments which are such a feature of Central Indian scenery, are built of horizontally bedded sandstones and shales of the Vindhyan system. The **Aravalli** mountains received their last major uplift at the end of the Vindhyan period, for the Vindhyan strata flanking the Aravallis to the east are involved in the orogenic flexures. The plane of contact of the Vindhyans against the older rocks of the range is a 'boundary fault', traced for some hundred miles. All through the Palæozoic and Mesozoic this mountain range, stretching from Gujarat to as far as the Himalayas, was the most important feature in India's geography. At the present day, after the wear and tear of long ages, it is reduced to mere stumps of this once dominating chain.

The Palæozoic Era in India.

The **Dravidian Era** is unrepresented in the Peninsula in its entirety. In the Himalayas the whole group is found developed in a more or less continuous Palæozoic sequence of marine strata, which by reason of their fossil remains can be correlated with the European sequence with sufficient accuracy to warrant their designation by such names as Cambrian, Silurian, Lower Carboniferous, etc. Succeeding the Vindhyan Era in the Peninsula there is a great break in the geological sequence, in other words a number of geological ages pass away without leaving any record of rocks, signifying that no sedimentation took place during the interval but that the surface of the land was exposed to the action of the subaerial agents. This last interval, encompassing the whole of the Dravidian era, from the Cambrian to Upper Carboniferous, denotes another great *regional unconformity* in the geology of India.

In the extra-Peninsular mountains of Kashmir and Spiti in the Central Himalayas, there occurs a complete and conformable sequence of marine strata characteristic of the **Cambrian, Ordovician, Devonian,** Lower and Middle **Carboniferous.** A succession of marine faunas of brachiopods, trilobites, corals and cystoids enables a more or less precise classification and correlation of this series to be made with the Palæozoic divisions of the rest of the world. The best studied areas of Himalayan Palæozoics are Spiti and Kashmir; the following table gives the succession in the two areas :—

	Spiti Valley	Kashmir
Upper Carboniferous	Productus series. Basal conglomerates.	Volcanic agglomerates, slates, containing *Gangamopteris*, fossil fish.
Middle Carboniferous	Po series—black shales with *Fenestella*, brachiopods and some fossil plants.—2,000 ft.	*Fenestella* series—quartzites, shales and conglomerates. Brachiopods, corals, polyzoa.—3,000 ft.
Lower Carboniferous	Lipak series—limestones and quartzites with brachiopod fauna.—2,000 ft.	*Syringothyris* limestone—flaggy limestone, shales and quartzites with locally rich fauna.—3,000 ft.
? Devonian	Muth quartzites—well-bedded white quartzites, unfossiliferous.—3,000 ft.	Muth quartzites—snow-white series of unfossiliferous quartzites.—2,000 ft.
Silurian Ordovician	Coral limestones, dolomites, flaggy quartzites with cystoids and trilobites. Up. and Lr. Silurian.—2,000 ft.	Silurian of Lidar valley. *Orthis, Calymene, Phacops, Illænus*, etc.—100 ft.
Cambrian	Haimanta system—red and black slates, quartzites and dolomites. *Olenus, Microdiscus, Lingulella.*—2,000 ft.	Massive clays, sandy slates with limestone lenses. *Agnostus, Conocoryphe, Anomocare* of Upper and Mid. Cambrian affinities; *Obolus, Acrothele, Lingulella.*—7,000 ft.

In the Salt Range mountains of the Punjab the **Cambrian** system is developed in the eastern scarps of the range, exhibiting the following section :—

Salt-pseudomorph shales—450 ft.

Magnesian sandstones, sandy dolomites, with *Stenotheca*—250 ft.

Neobolus shales—black, sandy shales with brachiopods, *Redlichia, Olenellus*, etc.—100 ft.

Purple sandstone—450 ft.

The Palæozoic land-period of India

Succeeding the Cambrian there occurs a big gap in the Palæozoic sequence of the Salt Range, the next overlying member being the basal beds of the Upper Carboniferous. This mid-Palæozoic unconformity is of wide prevalence in N.-W. Punjab, Hazara and W. Kashmir, in all of which the marine Silurian, Devonian, Lower and Middle Carboniferous are either absent altogether, or represented by isolated basins of unfossiliferous sediments of probably continental origin. Thus the enormous Dravidian land period of peninsular India also prevailed in some parts of Northern India. Since the creation of the Aravalli chain and certain minor systems of flexure in the Satpuras and on the East Coast, all mountain-building movements died down in the Peninsula and it has since remained a high and dry land-mass subject to some vertical movements of the crust, of the nature of dislocations, but not to any lateral or tangential movements of the fold-producing kind.

Geographical changes at end of Dravidian Era

The commencement of the Upper Carboniferous is a most important land-mark in the geological history of India. It ushered in an era of powerful earth movements and of profound geographical changes. In both the areas these changes were initiated by an **Ice Age,** which has left its characteristic marks at a number of centres over India in glacial boulder-beds and conglomerates. The extra-Peninsula witnessed a marine invasion and deepening of the sea-floor, on the present site of the Himalayas, from Hazara to Assam—the transgress of the great Mediterranean Sea from the west, the **Tethys** of geologists. There began to be deposited on the floor of this sea the vast pile of marine sediments which commenced with the Upper Carboniferous and ended with the Eocene, *i.e.*, the whole duration of the Aryan Era.

In the Peninsula, the end of the Dravidian and the beginning of the **Aryan Era** brought in different kind of earth movements and a new chain of events. Here the earth-stresses manifested themselves in producing tensional cracks and fissures and in the subsidence of large linear tracts, giving rise to chains of basin-shaped depressions in the old gneissic terrain. The drainage of the land discharging its load of sediments into these depressions, ultimately filled them up with a system of land and river deposits, burying in them countless remains of land-inhabiting plants and animals.

THE GONDWANA SYSTEM OF THE PENINSULA.

Thus, henceforth we have to consider a dual facies of deposits in India during the succeeding Palæo- and Mesozoic systems—a marine facies in the extra-Peninsula and a fresh-water and terrestrial facies in the Peninsula. This latter system of land deposits is

known in Indian geology as the **Gondwana System** from the typical basins of these rocks occurring in the Gond country to the south of the Narbada. It is of wide distribution in the Damodar, Mahanadi, and Godavari valleys, in the Satpuras, and in smaller patches in a number of far distant outliers in the Salt Range, Kashmir, Sikkim and Abor Hills. The accumulated drift of the dense forest vegetation which peopled Central India in those days has given rise to thick seams of coal 20 to 80 feet thick in the lower part of the Gondwanas, which thus constitutes one of the most productive geological horizons in India, supplying 23 million tons of coal per year. Some iron-ore also is associated with the coal seams. The Gondwana System is divided into two parts, Lower and Upper; a thick zone of intervening strata, exhibiting intermediate characters, is sometimes separated as the Middle Gondwana division. The Lower Gondwanas range in age from the Permo-Carboniferous to the Trias. At its base is a glacial **boulder-bed** of wide-spread occurrence from Orissa to the Salt Range and Hazara, containing ice-scratched pebbles, testifying to the prevalence of glacial ice covering the land surface of India as far south as Lat. 20°. This is overlain by a thick series of coal-measures—the **Damuda series.** This series, at places 10,000 feet thick, and carrying the most important coal deposits of India, is divided into :—

Coal-measures of the Lower Gondwana

Raniganj stage.
Ironstone Shale, or Barren Measures stage.
Barakar stage.

These stages are well recognized in the Damodar valley, but are not easily identified in the other Gondwana areas, where they are designated by a number of local terms. The Damuda series is overlain by the **Panchet series** of greenish sandstones and red shales with some coal-seams, containing fragmentary remains of labyrinthodonts and reptiles. A prolific flora (the *Glossopteris* flora) in which the preponderant element was the seed fern, *Gangamopteris*, *Glossopteris*, etc. together with some *Cordaitales*, characterizes the Damuda series. The Middle and Upper Gondwanas evince a change of physical conditions from the arctic cold of a glacial epoch to a semi-desert type of climate and the disappearance of the luxuriant forest vegetation of the earlier epoch. The prevalence of thick red, iron-stained sandstones and shales point to a drier and warmer climate. From the evidence of the contained fossils of reptiles and of plants, with a preponderance of the coniferous and cycadaceous orders of the gymnosperms, the geological range of the Upper Gondwanas is determined to be from Upper Trias to Lower Cretaceous. The

Changes in climatic and physical conditions

ferns, horse-tails and seed-ferns of the lower division are replaced by conifers and cycads, and in one or two cases by a still higher order of plants, in the Upper Gondwanas, while the fishes and labyrinthodonts are succeeded by reptiles.

Distribution of the Upper Gondwanas

The Upper Gondwanas of the Satpura area, well exposed in the gigantic scarps of the range, are distinguished as the **Mahadeva or Pachmarhi series,** mostly composed of sandstones, 10,000 feet in thickness. In the Godavari valley a similarly constituted group is named the Kota-Maleri series, containing the fish *Ceratodus* and the reptiles *Parasuchus* and *Hyperodapedon*. In the Rajmahal hills a quite different rock-facies prevails—2,000 feet of basaltic lava-sheets interbedded with shaly sediments containing a well-preserved flora, some members of which have reached the stage of evolution of angiosperms and hence mark an uppermost Jurassic or Lower Cretaceous horizon. A similar age is ascribed to the Upper Gondwanas of Cutch, the Umia beds, which contain along with a Gondwana flora, intercalated marine beds with *ammonites* of Neocomian horizon. Upper Gondwanas outcrop at a few places on the East Coast containing fossil plants of Rajmahal affinities; they also are associated with marine intercalations entombing *Trigonia* and *ammonites* of Lower Cretaceous age.

The Gondwana system of river deposits, occurring in scattered basins, which continued to sink *pari passu* with deposition for such a long section of geological time, is of unique significance and illustrates the peculiar physical structure of the Indian sub-continent. During this period in the Tethys Sea, bordering Gondwanaland to the north, there were being deposited marine sediments bearing characteristic fossils pertaining to the ages Permo-Carboniferous, Permian, Trias, Jurassic and Cretaceous.

Parallel deposits in Africa and Australia

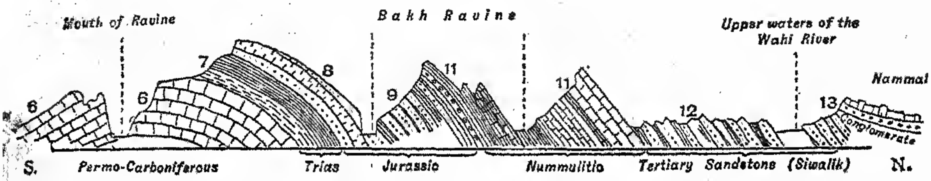
A more or less similar group of river-borne land deposits, containing coal-measures and commencing with a glacial conglomerate at the base, is found in Australia, Madagascar and South Africa, containing a fossil flora which possesses many affinities with the Indian Gondwana flora. Some marine inclusions near the base of the series, occurring in the Salt Range, Kashmir and in New South Wales (Australia), contain closely related species of *Eurydesma*. From this fact, as well as from important discoveries of nearly allied species of fossil reptiles in the Jurassic and Cretaceous of India, Africa and Patagonia, it is argued that land connections existed between these distant regions, across what is now the Indian Ocean, either through one continuous southern continent, or through a series of land-bridges and isthmuses, which extended from South America to India and united within its borders

An old Indo-African continent

the Malay Archipelago and Australia. To this old-world southern continent the name of **Gondwanaland** is given. This continent persisted as a prominent feature of the Southern Hemisphere from the end of the Palæozoic, through the whole length of the Mesozoic, to the beginning of the Cainozoic, when it disappeared as an entity by fragmentation and drifting away of its constituent blocks, or by their foundering. The north frontier of this Indo-African continent was the shore of the Himalayan sea, the Tethys, which stretched from the south-west extremity of China to the present Mediterranean.

The marine period of the Extra-Peninsula.

A totally different sequence of geological events was taking place in the extra-Peninsula during the Gondwana Era, resulting



TEXT-FIG. 1.—A typical transverse section across the Salt Range showing sequence of strata from Upper Carboniferous to Tertiary (Scale: 3 inches = 1 mile).

in the formation of a quite different set of rocks which have preserved in them a wealth of the marine animal population that was contemporary with the various stages of the Gondwanas. The Permo-Carboniferous and Permian chapter in this history is represented in the Salt Range by one of the most perfect marine developments seen anywhere in the world. Every stage in the sequence, from the Uralian to the uppermost Permian, grading imperceptibly into the Trias, is present, bearing its characteristic suite of fossils. The Salt Range succession begins with a boulder-bed or till, composed of striated and facetted boulders of crystalline rocks from the south, embedded in a silty matrix. This is overlaid by olive shales and sandstones (*Conularia* beds) containing *Eurydesma* and other fossils allied to those of the glacial beds underlying the coal-measures of New South Wales. An overlying group of mottled sandstones and clays has preserved impressions of *Gangamopteris* and *Glossopteris*, genera so wide spread in the Lower Gondwana areas of the south-east. The next formation is about 700 feet of deeper water marine limestones still containing occasional intercalations

of plant-bearing beds, differentiated into three well-marked divisions, Lower, Middle and Upper **Productus Limestone**, each again sub-divided into stages and zones dominated by some species of *Productus* or, in the upper stages, by some precocious genera of *ammonites*. Among the brachiopods characteristic of the Lower Productus are *P. spiralis*, *P. semireticulatus*, *P. cora*, associated with the aberrant genus *Richthofenia* and the foraminifer *Parafusulina*. The commonest Middle Productus forms are *P. lineatus*, *P. indicus* with *Oldhamina* and *Lyttonia*; *Xenodiscus* occurs with this division, together with *Coboceras* and *Foordiceras*. The Upper Productus Limestone marks still more the approach of Trias by the presence of many genera of true ammonites, *e.g.*, *Cyclolobus*, *Medlicottia*, *Popanoceras*, *Tænioceras* and *Arcestes*.

Permo-Carboniferous, Permian and Mesozoic of the Salt Range

The occurrence of Lower Gondwana plants in close association with marine fossils at the base and middle of the Productus limestone is an event of much importance and serves to fix the lower limit of the Gondwana System as well as the age of the Palæozoic glaciation of India within narrow limits. An exactly similar association of Damuda plant-beds in several localities in Kashmir with volcanic slates and tuffs of the Panjal Volcanic series, fortunately dated by the occurrence in them of crowds of species of *Productus* and *Spirifer* at two or three distinct levels, and their superposition by the marine Zewan series, correlated by Cowper Reed with the Middle Productus horizon of the Salt Range, further supplements this evidence.

The long marine history of the Himalayas during the Aryan Era

In the broad, slowly sinking ocean floor of the Tethys, during this interval, a great thickness of shales and limestone, crowded with lamellibranchs, crinoids and ammonites was being laid down. The rate of deposition keeping pace with the submergence of the ocean-bottom, there has resulted a pile of thousands of feet of shallow-water as well as deep water strata representative of the **Permian, Trias, Jurassic, Cretaceous** and **Eocene** periods. The following table summarizes in bare outline the main chapters in the marine Himalayan record as it is laid bare in the great escarpments of the Tibetan plateau :—

Eocene ..	**Nummulitic limestones** and shales of Ladak and S.E. Tibet, with contemporaneous basic volcanics ..	2,000 feet.
Cretaceous ..	**Chikkim series** of white limestones and shales; **Giumal series**: Flysch of Central Himalaya; Volcanic series of Burzil and Dras; Massive acid and basic plutonics ..	6,000 feet.
Jurassic ..	**Kioto limestone** and dolomites overlain by the **Spiti shales** from Hazara to east of Nepal ..	4,000 feet.

Triassic ..	Lower, Middle and Upper **Trias** commencing with the **Otoceras zone**; limestones, dolomites and shales of Kashmir, Spiti, Garhwal and Kumaon	5,000 feet.
Permian ..	**Productus Limestone,** Kuling and Zewan series; Sirban limestone, Krol limestone of the Outer Himalayas	3,000 feet.
Upper Carboniferous	**Panjal Volcanic series** of Kashmir with marine and Gondwana intercalations; Infra-Krol series. Glacial conglomerates of Simla (**Blaini series)** and of Hazara (Tanakki beds)	8,000 feet.

The lateral zoning of the Himalayas

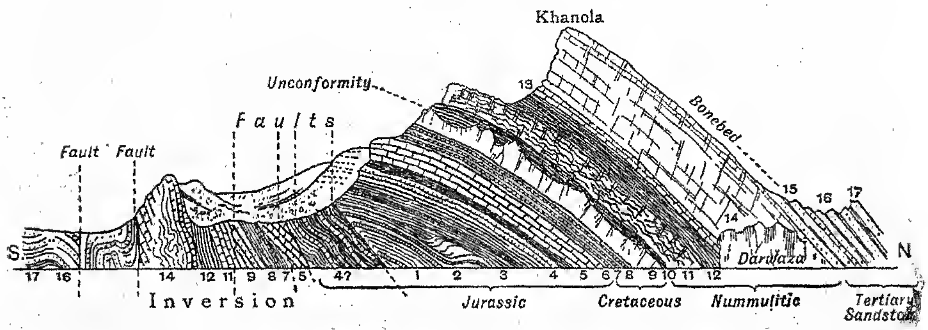
The above section of strata, particularly from the Trias upwards to the top of the Cretaceous, together with the underlying equally interesting Palæozoic section from the Cambrian to Middle Carboniferous, is exposed in the series of magnificent escarpments to the north of the central Himalayan axis, in Spiti, Garhwal and Kumaon and further east in Sikkim, where the Tibetan plateau ends in gigantic cliff faces. This is known as the **Tibetan Zone** of the Himalayas in distinction to the central or **Himalayan Zone** of unfossiliferous slaty and crystalline rocks building the middle ranges of the mountains, and the outer or **Sub-Himalayan Zone** composed mainly of middle and upper Tertiary. The long and uninterrupted Himalayan marine period, from the Uralian to the middle Eocene, preserving successive dynasties of fossil faunas, showing kinship with the Alpine and other European Mesozoic areas, is a notable event in earth-history and marks out the Tibetan sections as some of the most perfect and legible expositions of the stratified crust of the earth. There are no unconformities or lost intervals in the sequence; the Aryan era of the Himalayas thus runs astride the limits of the Mesozoic Era of the standard geological scale. Their inaccessibility behind the lofty central ranges is, however, a great drawback, a difficulty only removed in part by the more accessible sections exposed in the Kashmir mountains. The Kashmir sections, however, are partial and not so continuous; they are also often concealed under glacial and other debris.

The Himalayan geosyncline

Portions of the sea-floor subsiding in the form of immense troughs, concurrently with deposition of great thickness of sediments, as in the above example, are called geosynclines. The immense accumulation of strata in geosynclines ultimately disturbs the gravitative equilibrium of the crust and during the next succeeding periods of earth-deformation these loaded and consequently weakened belts come to be wrinkled up to form the mountain-chains of the world.

They are thus singled out as the weaker and more flexible portions of the earth's circumference, in contrast with the stable and rigid blocks such as the Peninsulas of Africa and India (horsts).

In contrast with the unique Mesozoic development of the geosynclinal facies of the Himalayas, the records of the Salt Range Mesozoic are patchy and consist of coastal shallow-water deposits. Only the lower Trias (*Ceratite* beds) is represented, overlain by middle and upper Jurassic beds exhibiting a rapidly varying lithology, enclosing some coal-seams. The Cretaceous (Neocomian) is of inconspicuous thickness and extent, being restricted to the trans-Indus extension of the Range.



TEXT-FIG. 2.—Section showing inverted folding and faulting, Chichali, Shekh Budin hills.

MARINE TRANSGRESSIONS IN THE PENINSULA.

To revert to the Peninsula's history of the Aryan Era, interrupted since the close of the Gondwana period. There occurred during the Jurassic and Cretaceous several minor inroads of the sea on the coastal fringes of the Indo-African continent, which was probably not yet dismembered. In one of these in the Upper Jurassic in Cutch there was laid down 6,000 feet of fossiliferous limestones, marls, and sandstones preserving a highly diversified but more or less provincial cephalopod fauna, which has enabled a fourfold division of the rocks into Patcham, Chari, Katrol and Umia series, ranging in age from Bathonian to the Neocomian. This marine invasion penetrated as far north-east as Jaisalmer in Rajputana. 114 genera and 600 species of ammonites have been identified, of which a great many are purely local types unknown elsewhere. Of the rest, the Cutch Jurassic fossils present no affinities with the Mediterranean or north-west European province, but they show kinship to the Jurassic faunas of Madagascar. In another of these transgressions of the sea, the Trichinopoly coast was submerged and covered with some 3,000 feet of richly fossiliferous grits, sandstones and clays, in which are preserved more than 1,000 species of marine molluscs, the majority of them being ammonites,

Cretaceous marine deposits

disclosing close relationship with the Cretaceous of Madagascar and Natal. Four well-marked stages are recognized in the Trichinopoly Cretaceous, whose correlation with the European stages is shown below :—

Niniyur stage with *Nautilus danicus*..........	Danian.
Ariyalur stage with *Trigonoarca galdrina*....	Senonian.
Trichinopoly stage with zonal distribution of *Placenticeras* and *Pachydiscus*............	Turonian.
Utatur stage with zones of *Mammites*, *Acanthoceras* and *Schloenbachia*.............	Cenomanian.

Assam and the Narbada valley witnessed similar temporary invasions of the sea during the Upper Cretaceous, vestiges of which are seen in patches of marine deposits containing fossils characteristic of the time. In the Narbada valley these are known as **Bagh beds.** The Bagh fossils are distinct types, showing greater affinity with the Cretaceous of Arabia and Europe than with the adjacent Assam or Trichinopoly province. This dissimilarity shows that the two seas were still separated by some great and far-reaching land-barrier. The **Lameta beds** are a thin zone of fresh-water and estuarine beds of the same or slightly newer age than the Baghs, covering a wide extent of the ground underlying the Deccan Trap. They are of stratigraphic value by reason of their infra-trappean position and the 12 genera of Dinosaurian reptiles that are preserved in them.

THE DECCAN TRAP VOLCANIC PERIOD.

At the end of the Cretaceous, and according to recent discoveries, well after the commencement of the Eocene, the Deccan experienced a period of intense volcanic activity of a type that has no parallel among the volcanic phenomena of the modern world. Several hundred thousand square miles of the country were flooded by quiet outpourings of basaltic lava from fissures in the earth's surface which was eventually converted into a plateau several thousand feet high **(Deccan Trap).** The denudation of ages has carved out this plateau into numerous isolated, flat-topped and square-sided hill-masses which are to-day such a feature of the landscapes of the Western Ghats. In the dissected sides of these peculiar ghat-shaped hills we see to-day the piles of bedded basalts, in 20 to 80 feet thick horizontal flows, separated by thin partings of sediments, **inter-trappean beds.** The inter-trappean beds are fossiliferous and are thus valuable as furnishing the history of the periods of quiescence which intervened between the volcanic outbursts and of the animals and plants that again and again migrated to the quiet centres. Numerous palms and some flowering plants, together with fishes, frogs, and various orders of reptiles flourished at this period in the Deccan, the petrified remains of

which, from this and adjoining areas, bear witness to the advanced, more evolved forms of life that superseded the land life of the Gondwana period.

The Deccan trap magma is generally an undifferentiated amygdaloidal basalt, or dolerite, of normal composition, but there are a few centres, *e.g.*, Girnar in Kathiawar and Pawagarh hill near Baroda, where acid and ultra-basic variations of the prevailing magma are met with, both in their intrusive and extrusive forms. A host of zeolitic and secondary minerals have been noted in vesicular cavities, as well as interstitially, in the lavas. Ash-beds are common, with a few glassy and pumicious forms of lava, but agglomerates and coarse tuffs are absent, thus excluding any signs of explosive volcanic action during the eruptions. Swarms of dykes of dolerite traversing the bedded flows for long distances and extending through the bordering terrain are seen all along the periphery of the trap area, marking the sites of the fissures of eruption.

Probably associated with the Deccan trap eruptions are the early Tertiary gabbro, peridotite and granophyre intrusions of Baluchistan, carrying the important chromite segregations of the Quetta and Zhob districts, and the serpentinized peridotites of Burma, with their included masses of the much-prized mineral jade.

Geography of India at beginning of Tertiary Era.

The Deccan traps mark the advent of the **Cainozoic or Tertiary Era** *of earth-history*. Great changes in physical geography adumbrate the new era; of these the most momentous were the breaking up of Gondwanaland into the now severed lands of Africa, India, and Australia, and the initiation of earth-movements which culminated in the lifting up of the Himalayan geosyncline from the bed of the Tethys Sea into the loftiest mountains of the world. It is probable that the outpouring of thousands of feet of Deccan trap lavas from the interior of the earth was in some way a prelude to the stupendous release of geodynamic energy in later Tertiary times. The backbone of Tertiary India, its main water-shed, was the Vindhya range with the Kaimur hills continued north-east by the Hazaribagh-Rajmahal hills and the Assam ranges. This water-divide separated the northerly drainage flowing into the remnant of the Tethys (left after the first mid-Eocene uplift of the Himalayas) from the southward flowing drainage into the Indian ocean. There were then two principal gulfs—the Sind gulf, extending north through Cutch, Punjab, Simla and Nepal; and the eastern gulf of Assam and Burma, separated into two by the meridional ridge of the Arakan Yoma. The Gangetic plains were then a comparatively featureless expanse of rocky country, sloping northwards from the central Indian highlands towards the Sind gulf.

MARINE AND DELTAIC FACIES OF THE TERTIARIES.

The Tertiary history of India is recorded in the thick sedimentary deposits filling these two gulfs. As these dwindled and receded, they were replaced by the broad estuaries of the rivers that succeeded them, *e.g.*, the Indus in the former case and the Ganges and Brahmaputra in the case of the latter. The earlier marine deposits were steadily replaced by the growing estuarine and deltaic sediments of the rivers superseding them.

Except for a few small patches near the coasts, the Tertiary deposits of India are restricted to the extra-Peninsular mountains. The ranges of Sind, Assam and Burma, and the sub-Himalayan zone, along its whole length, are almost entirely composed of these rocks, of which the lower, Eocene and Oligocene, are marine, while the upper, Miocene and Pliocene, are of fresh-water and sub-aerial deposition. In the Sind hills, the area taken as the type of the Tertiary succession for the rest of India, the group is classified as follows :—

Manchar series (Siwalik) 10,000 feet.	Grey and brown sandstones and conglomerates with fossil mammals.	Up. Pliocene.
Gaj series 15,000 feet.	Marine limestones and shales overlying fresh-water strata, with land-mammals.	Up. Miocene. Lr. Miocene.
Nari series 6,000 feet.	Upper part, fresh-water sandstone; lower part, marine limestones with foraminifera.	Oligocene.
Kirthar series 9,000 feet.	Massive Nummulitic limestones and shales, highly fossiliferous.	Upper Eocene.
Laki series 800 feet.	*Alveolina* limestone with calcareous shales and coal-measures.	Mid. Eocene.
Ranikot series 2,000 feet.	Marine foraminiferal limestones underlain by coaly and gypseous shales.	Lower Eocene.
	Cardita beaumonti beds ..	Upper Cretaceous.

Salt, Coal and Petroleum associated with Eocene and Miocene

A more or less full sequence of Tertiary rocks is met with in the Salt Range, the Potwar plateau, the Punjab foot-hills, Assam and Burma, many of whose stages are correlatable to the Sind sequence. The lower part of the Tertiary is of economic value because of the association of rock-salt, coal and petroleum with the Eocene and Miocene rocks of Punjab, Assam and Burma. The rock-salt occurs in beds up to some hundred feet thickness in the Laki series of the Salt Range, in the adjacent Kohat area and in the Mandi State near Simla. The rock-salt mines of these localities supply 170,000 tons of salt annually, the whole of which is used for human consumption. About 450,000 tons of coal is mined from the coal-measures of the Ranikot-Laki series, while petroleum is the product of a somewhat higher horizon (Oligo-

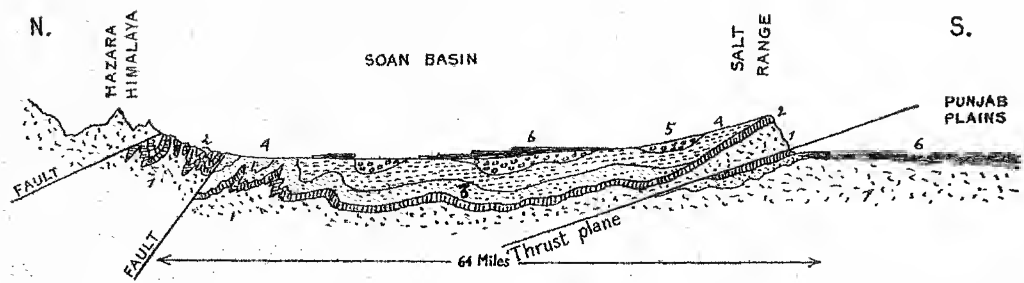
cene to Miocene) yielding nearly 250 million gallons from the Burma oilfields and 53 million from Assam, per year. The Khaur and Dhulian oilfields on the Punjab Tertiaries, producing 15 million gallons yearly, derive their oil from the Eocene Nummulitic limestone and overlying Murrees.

The fossil wealth of the Siwalik System.

The most important upper Tertiary formation, from the palæontological point of view, is the **Siwalik System** (Lower Miocene to Lower Pleistocene). It is a group of river and subaerial deposits, sand-rock, clays and conglomerates, 16,000 feet thick, of remarkable uniformity of composition and character, stretching in a long continuous band from Sind, through the Punjab (where it attains its greatest width), to Nepal and Assam. The Siwaliks are constituted of the debris brought down from the newly upheaved Himalayas by the numerous transverse rivers and deposited in the broad valley of a north-westerly flowing river, which carried the combined discharge of the present Brahmaputra, Ganges and Indus to the head of the Sind gulf. This river is named *Indobrahm* by Sir E. Pascoe. This system is noted for the wealth of fossil species belonging to extinct families of elephants, rhinoceroses, horses, giraffes, pigs, apes, deer, antelopes, bovids, camels and carnivores; these animals are not far distant in age from our time and therefore are the immediate ancestors of our existing land mammalia. The prolific remains of their skeletons, skulls, teeth, bear witness to the abundance of the higher terrestrial life of those days before which the present world looks impoverished. The Siwaliks have preserved the remains of nearly 15 genera of anthropoid apes, the highest mammal in the then existing living world, some of which are believed to be links in the line of human ancestry, and it is possible that future research may bring to light some remains of Primitive Man from the top beds of the Siwaliks.

Pilgrim has classified the Siwalik system as follows, based on various mammaliferous horizons :—

Upper Siwalik 6,000–9,000 feet.	Boulder-conglomerate stage—coarse conglomerates, or thick, earthy clays: *Elephas, Equus, Bos.*	Lower Pleistocene.
	Pinjor stage—*E. planifrons, Hemibos.*	
	Tatrot stage—*Stegodon, Leptobos*	Up. Pliocene
Middle Siwalik 6,000–8,000 feet.	Dhok Pathan stage—massive sandstone and sand-rock; *Hipparion, Giraffoids, Hippopotamus, Stegodon, Mastodon.*	Pontian.
	Nagri stage—*Hipparion, Prostegodon* ..	Sarmatian.
Lower Siwalik 4,000–5,000 feet.	Chinji stage—deep, red, nodular clays with few sandstones; *Tetrabelodon, Giraffokeryx, Listriodon, Mastodon, Dinotherium.*	Tortonian.
	Kamlial stage—dark, hard sandstones with purple clays; *Anthracotheroids, Aceratherium.*	Helvetian.



TEXT-FIG. 3.—Section across the Potwar Geosyncline.

(1) Pre-Tertiary; (2) Eocene; (3) Murree Series; (4) Lower Siwalik; (5) Upper Siwalik; (6) Sub-Recent.

Three phases of uplift of the Himalayas.

With the end of the Siwalik epoch the last phase of Himalayan upheaval was completed, for at many localities in the foot-hills tightly folded upper Siwalik strata stand on edge, or have been thrust over later Pleistocene alluvium. The two earlier phases of Himalayan uplift were (1) the post-Eocene, which drove back the last remnants of the Nummulitic sea of the Himalayan area and upheaved the ocean floor to rise in one system of crustal folds. The nummulitic limestone is at places elevated 15,000 to 20,000 feet; (2) post-Miocene, which raised the zone of Murree-Kasauli sediments into the lesser Himalayan zone, imparting to it complicated flexures and thrusting it under the older Tertiaries.

The parallel lines of reversed faults in the Tertiary zone of the sub-Himalayas of the Punjab, Kumaon and Nepal designated as the 'Boundary Faults' by Medlicott and Middlemiss, mark the periodic uplift of the mountains accompanied by the encroachment of the mountain-foot more and more towards the rapidly filling depression to its south.

Recent views about structure of the Himalayas

Recent work in the Kashmir, Simla and Garhwal Himalayas has thrown some light on the structural plan of these mountains and revealed the existence of thrust-planes of great magnitude, by which immense recumbent sheets (*nappes*) of the inner Himalayas have slid forward and come to lie on the newer rocks of the outer zone. At least two such thrusts have been clearly marked, one along which the younger Tertiaries of the sub-Himalayas are brought either against the Nummulitics or Permo-Carboniferous (Panjal or Blaini or Krol series) and another, along which the latter are overthrust by the great recumbently folded sheets of the crystalline and metamorphic Purana, or still older sediments, of the inner zone. The roots of the latter nappes, or sheet-folds, are not autochthonous, but lie much to the north in the central axial zone of the Himalayas.

The Quaternary Ice Age.

The end of the Siwalik epoch witnessed, in common with many regions of the northern world, a great refrigeration of climate which culminated, in the Himalayan region, in an **Ice Age**, during which the greater part of the land surface was buried under a cap of ice. In the rest of India, situated below Lat. of 30°, the cold was not intense enough to cause glaciers to flow over its surface but it gave rise to a succession of cold, rainy periods (Pluvial period) which induced notable changes in the habitat and distribution of the then living fauna and flora of the Peninsula. In the Himalayas the records of the Quaternary ice age are clear,

both in the glaciated topography of the valleys and ranges and in the accumulations of moraines, erratics, rock-striations, roches moutonnées, etc.

FORMATION OF THE INDO-GANGETIC TROUGH AND ITS FILLING UP.

The Indo-Gangetic Alluvium: The geotectonic stresses involved in the erection of the Himalayas produced in the northern part of the Peninsular foreland a concomitant sag or depression, at the foot of the mountains. This wide trough between the Vindhyan-Kaimur highlands and the northern mountains was, in the Eocene time, occupied by an arm of the sea; the scattered chain of nummulitic outcrops, extending from Naini Tal to the Kala Chitta hills near the Indus, are the memorials left by that sea. As this sea gradually retreated after the Eocene it was superseded by the broad estuary of the north-westerly flowing river referred to on p. 62, which traversed the whole breadth of India from Assam to the north-west corner of the Punjab and then turned south to discharge into the Sind gulf. It was in this river-basin that the Murree and Siwalik series were formed. This north-westerly drainage was disturbed in mid-Pleistocene time by differential earth-movements and the old great river was dismembered into the three separate river-systems of the Indus, Ganges and Brahmaputra. The depression still left began to be filled up by the silt brought down from the high ground by the hydra-headed tributaries of the Indus and Ganges. Each fresh uplift of the mountains must have rejuvenated the streams, thus multiplying their carrying capacity and aggrading power. On emergence from the steep gradient of their mountain-track, these streams discharged their burden into the depression, eventually filling it up and converting it into the low, flat, level plains of the Punjab, the United Provinces, Bihar and Bengal.

Estimates about the depth of the alluvium in the Indo-Gangetic trough vary from 6,500 feet to 15,000 feet. The trough is not of uniform depth along its whole length; it is probably at maximum depth between Delhi and the Rajmahal hills and shallow in Rajputana and Assam. Nor is the floor smooth, for several corrugations and ridges have recently been observed underneath the alluvium by gravimetric surveys carried out by the Geodetic Survey of India. The northern rim of the trough, where it merges into the Himalayan foot-hill zone, is one of considerable tectonic strain; it is the site of the long parallel fractures of boundary fault type (p. 64) and it is conceivable that the alluvium conceals a zone of similar folding and faulting further south. The seismic belt of India runs along the north margin of the plains; the epicentres of the majority of the great Indian earthquakes since the XV Century lie in this zone.

The earthquake belt of India

LATERITE.

The peculiar rock-formation known as **Laterite,** occurring as a cap over the surface rocks of tropical, monsoon-swept countries, is of wide distribution in the peninsular part of India from Assam to Cape Comorin. It is a reddish or mottled vesicular clayey rock, pisolitic or massive, composed of a mixture of hydrated oxides of alumina and iron, with smaller percentages of other oxides. There is generally no clay in typical laterite, the silica present is colloidal, mechanically held and not combined with alumina as kaolin. The base of many laterite deposits is bauxite and there are numerous varieties of laterite which have a large proportion of bauxite at one end and an indefinite mixture of iron hydroxides at the other end of the series. The rock is subject to many secondary chemical and segregative changes and hence presents numerous modifications in the field. Laterite occurs principally as a superficial cap on the basalt of the Deccan highlands but it is not confined to this rock and overspreads other formations as well. It caps plateaus ranging in height from 2,000 to 5,000 feet, the thickness of the cap varying from 50 to 200 feet commonly. Laterite deposits have economic value, being used at places as ores of iron or aluminium, as a source of aluminous cement and, from the facility with which it can be cut, when fresh, into blocks, as a building and road-making material.

SUB-RECENT.

Among the deposits that belong to geologically recent or sub-recent age may be mentioned the following diverse kinds: the high-level terraces of the principal rivers, coastal deposits, some raised beaches and submerged forests, wind-blown sands (of the Rajputana and Cutch deserts), loess, some cave-deposits, the black cotton-soil of Gujarat and Deccan, the ossiferous gravels of the upper Sutlej and Narbada and the Karewas of Kashmir. With many of these are associated relics of Prehistoric Man in India, his rudely fashioned knives, scrapers, celts, etc., made out of stone metal or bone. The principal sites from which palæolithic implements have been derived are the valleys of the Godavari, Narbada, Mahanadi and the Potwar plateau of N.-W. Punjab. Here we reach the limit of geological history; further inquiry lies in the domain of Archæology and Anthropology.

TWO TYPE-AREAS FOR GEOLOGICAL STUDY IN INDIA.

In the above sketch of the geological history of India we have presented only a broad generalized account of the sub-continent in its barest outline. In by far the greater part of the country, the part in which the chief centres of population with their schools and universities are situated, the geological record is

highly imperfect and dis-continuous. Occurring in remote, fragmentary patches, the geologist's opportunities for field observation and study of this essentially out-of-doors science are greatly restricted. There are two localities in India, however, where the student of geology will find a considerable section of the most interesting divisions of the geological record laid bare in accessible sites. These two localities are: (1) the Salt Range mountains, and (2) the Valley of Kashmir.

Geological phenomena seen in the Salt Range.

The **Salt Range** is a continuous range of low, flat-topped mountains rising abruptly out of the Punjab plains. It extends from Long. 71° 30′E. to 73° 30′ with an approximately E.-W. strike from the Jhelum river to the Indus. It is a most important locality in India for the study of physical as well as stratigraphical geology, not only because it contains a very large portion of the stratified record of the Indian region, but because of the easily accessible nature and the clearness of the various sections laid bare in its hill-sides and valleys. Besides its stratigraphical and palæontological interest there is inscribed in its barren cliffs and dry gorges such a wealth of illustrations in dynamical and structural geology that this imposing line of hills can fitly be called a field-museum of geology. The striking structural feature of the Salt Range, a disrupted and thrust-faulted monocline, is the more or less level plateau top, ending on the one side in a line of steep escarpments overlooking the Punjab plains, and on the opposite, northern side, inclining gently towards the Kala Chitta hills and enclosing between them the Tertiary geosyncline of the Potwar. The general dip of the strata being to the north, the youngest Tertiary rocks are seen in the northern dip-slopes, while in the steep southern escarpments is exposed the fine succession of strata beginning with the Cambrian, through the Carboniferous, Permian, Trias, and Jurassic to the top of the Eocene, though the sequence is repeatedly interrupted and inverted by thrust-faulting.

The entire length of the range is faulted in a most characteristic manner by a number of transverse dip-faults into well-marked clean-cut tilted blocks. More important faults, regarding the tectonics of the range, are the reversed strike faults, often intensified into thrust-planes, by which slices of Cambrian strata have been repeatedly overthrust on to the Eocene, and these again over newer rocks. Recent work has made it clear that the foot of the range has undergone a horizontal displacement of many miles, being moved by pressure acting from the north along a gently inclined thrust (nappe).

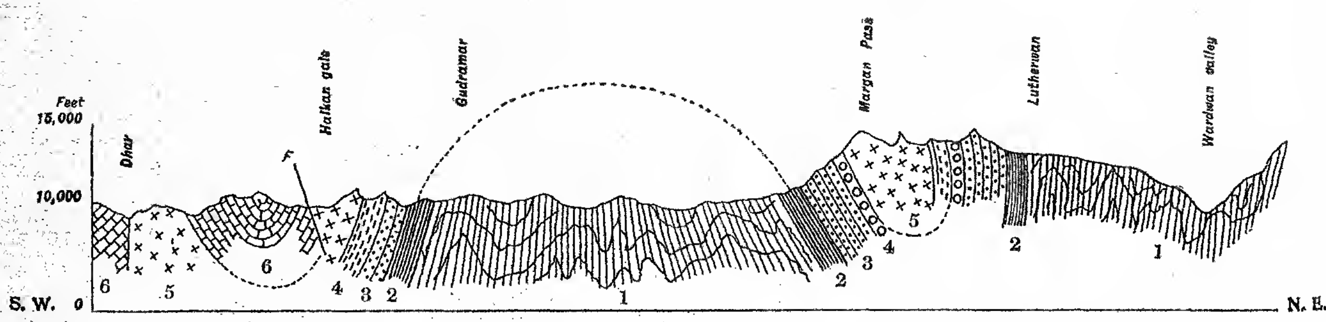
The name Salt Range is derived from the fact that its lowest beds, at the bottom of the cliffs, contain layers and lenses of pure rock-salt. Though occurring at the foot of the sections, this

position of the salt is adventitious and is due to the thrust-fault mentioned above.

Facilities for stratigraphic and tectonic work in the Kashmir Himalayas.

The **Kashmir Valley**: Kashmir possesses within a small geographical compass one of the best developments of the stratified geological record. A complete series of fossiliferous formations, from the Cambrian to the Trias is exhibited in the mountains immediately surrounding the beautiful valley, in localities accessible to the student and thus offering opportunity for stratigraphic work met with in no other part of India, except the Salt Range. The Kashmir mountains are a unique excursion ground as much for stratigraphic investigation as for their orographic and physiographic features, glaciers, lakes, etc. Representatives of all the major units of the geological column are present in the area. Of these, the upper Tertiary is well displayed in the foot-hills of Jammu, adjoining the Punjab, while the older Tertiaries are exposed in the outer ranges of the middle Himalayas. The whole of the Palæozoic, together with a grand development of the Trias is observed in the northern mountains, flanking the wide synclinal basin of the upper Jhelum valley. It is only for the study of the Jurassic and Cretaceous that the student has to go farther afield and to penetrate to the central ranges of the inner Himalayas.

In the orthoclinally built Pir Panjal range, forming the southern flank of the Jhelum valley syncline, the steep south-west face exhibits clear sections revealing the tectonics of this part of the Himalayas, its thrust-planes and great recumbent folds, while the gently inclined north-east slopes, covered under enormous glacial and lacustrine (Karewa) deposits afford excellent ground for study of Pleistocene geology and recent orogenics. It is from the story told by the Karewa deposits of the Kashmir valley that we come to know of the extreme youth of the Himalayas and that the western mountains of this chain have been uplifted from 5,000 to 8,000 feet since the advent of Man on earth.



TEXT-FIG. 4.—General section to show the disposition of the Palæozoic rock-systems of Kashmir.

(1) Lower Cambrian; (2) Silurian; (3) Muth quartzite (? Devonian); (4) and (5) Panjal Volcanic Series (Upper Carboniferous and Permian); (6) Upper Trias.

AN OUTLINE OF THE VEGETATION OF INDIA.

By

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CONTENTS.

GENERAL.

While a knowledge of the geographical and climatal features of India is essential to any understanding of its Flora these features can only be touched briefly in such a short account of the vegetation as is here proposed. The term India as used herein excludes the now separated province of Burma, also Ceylon and the countries to the north-west, Afghanistan, Baluchistan, etc., although passing references will be made to features of the vegetation of these especially where such features indicate differences or invite comparisons or otherwise throw light on the vegetation of India proper. It is not intended that this account should present other than a somewhat distant bird's eye view of the extremely varied communities of plants extending throughout the country. For a closer view the visitor must have recourse to the works themselves on which this outline is based as well as to herbaria and to wide travel, but if it serves the purpose of indicating the range and content of the country, vegetatively treated, and brings into relief the variety and richness of its flora this is all that is intended.

It is based largely on a collation of all those works which preceded the publication of Hooker's *Flora of British India* as well, of course, as of this last, but it attempts to take in matters of more recent origin, work scattered throughout the various provincial and local floras and lists. It draws very freely from the account of the Botany of India published in the *Imperial Gazetteer*

the treatment in which is copied as the best means of reaching the object now desired, and the material of which it is hoped to sift and condense as well as to augment where information acquired since publication of the Gazetteer is likely to be of interest.

India probably presents a greater variety of meteorological conditions, actions and features than any area of similar size in the world. Rainfall, with which is associated the humidity of the atmosphere and which more than any other meteorological condition exercises an influence on vegetation, varies from some 450 inches in the hills of Assam to the north-east of the Bay of Bengal, and from some 350 inches in certain portions of the Western Ghats to as little as 3 inches per annum in Sind. During the south-west monsoon from June to September the air is supersaturated with moisture in the coastal districts and in the hills, while during the dry weather it may in certain districts be so dry as to defy the ordinary methods of calculation for humidity. In one season of the year the plains of India are the scene of the most wonderful and rapid growth of vegetation, a season of plenty for man and beast, in another they become a dreary brown sunburnt waste where the herbivore starves by the multitude and where it passes the understanding of man how any creature dependant on vegetation can come through the season. Such are the extremes presented by humidity, such the effects on vegetation and such the results.

Temperatures, which would seem to be of considerably less importance to plant life than water supply but whose effects as exemplified in the altitudinal range of Himalayan vegetation are yet appreciable show scarcely less extreme conditions than does humidity itself. From Greenland's icy mountains to India's coral strand has its counterpart for the Botanist in all conditions from her own barren icy mountains to the relatively mild green belt that characterizes her strands. And in the plains of Upper Sind, as in the Pab desert, can be studied a vegetation that suffers at one time of the year a temperature reaching 130 in the shade and at another conditions approaching those of the winter of Europe.

The physical features or topography of India is second in its importance to her plant life only to the influence of climate. Here again a variety is evident that few if any areas of similar size in the globe present. In the north extending from Assam to Kashmir and running in a general north-westerly direction lies the massive range of the Himalayas with a vegetation richer and more varied than that of any other part of India if not of the world. This is separated from Peninsular India proper by the Indo-Gangetic depression, a broad belt of country through which in the west the Indus and its tributaries drain in a south-westerly direction to the Arabian Sea, while at no great distance from the source of this system the Ganges takes its rise to drain the great fertile plains of North-East India comprising the United Provinces, Bihar and

Bengal. In this Indo-Gangetic depression are found the greatest extremes of conditions for plant life. From a wide sun scorched desert in the west where plant life can scarcely exist we pass by gradation to the ever green delta of the Ganges a thousand miles distant.

India south of the depression is characterized by a backbone of mountains in the west running parallel to the coast, at no great distance from the Sea; on the north by the Aravalli range and the rising uplands of Central India and Chota Nagpur and on the east by the range known as the Ghats. Roughly these bound and contain the great central plateau, itself intersected mainly from a westerly to an easterly direction by the water system of the Godavari and Krishna and minor streams draining into the Bay of Bengal. To the south of the peninsula the ghats taper off in the Nilgiris and Cardamom hills to gentle smooth rounded slopes of green uplands. Between the ghats and the Sea there is a comparatively narrow flat or gently sloping belt where, as in the west, the vegetation is tropical, in the east much more scanty except in the vicinity of the river mouths.

The whole of the truly peninsular part of India comes more or less under the influence of the trade winds carrying their moisture-laden burden. The moderating influence of proximity to the ocean tends to temperatures showing less variations; climates are more equable and there is much less seasonal variation in the vegetation than is to be found in the more extreme conditions away from the sea or out of the way of the main monsoon routes.

When the geographical extension of India is considered, when the number of degrees of latitude, temperate and tropical, it embraces is kept in mind, and when one recognizes it a land rising from the level of the sea to heights above the limits of vegetation, with torrid and arctic arid and humid conditions, the variety and wealth of its flora need occasion no surprise.

Of the elements of the flora of India, the Malayan is dominant. This undoubtedly arises from the fact that the barriers set by climate and by the high uplands and mountainous frontiers to the infiltration of plants from the north and north-west are absent from Malaya. The sea is a still more effective barrier so that the African and to a still higher degree the Australian and American elements are less well represented than the European and middle east floras. No fewer than 570 European genera figure in the Indian lists, many of them, however, represented by a single species; and the middle eastern element is certainly, as is to be expected, not less prominent. How far the European plant element in India may be considered as native is a subject of speculation, but the recent influx of American species taken with their marked tendency to spread makes it possible to suppose that modern transport has been an agent and that before the era of Indian botanical work a considerable European element had by this means managed to reach and establish itself

in this part of the world. It is curious that although the Tibetan and Siberian floras only reach India in the alpine regions of the Himalaya the Chinese and Japanese floras are strongly represented in its temperate belt.

An examination of the Flora of India reveals the outstanding peculiarity that not one of the families of flowering plants is peculiar to it; and if the genera common to India and some adjacent countries be excluded few endemic genera remain, and such of them as are endemic are local and with few exceptions are restricted to one or few species. When, therefore, the immense range of conditions that India presents for plant life be considered it is an enigma that its flora can yet be considered as merely an aggregation of several floral types.

The Australian element in the Indian flora is curiously represented by certain species of genera that are all but endemic in the southern continent, namely, *Baekia*, *Leptospermum*, *Melaleuca*, *Leucopogon*, *Stylidium*, *Helicia* and *Casuarina*. *Oxybaphus* of the Himalayas is otherwise a purely American genus. *Pyrularia edulis* is linked geographically to Java and North America and *Vogelia* to South Africa and Socotra. There are curiously no Myoporaceæ, Empetraceæ or Cistaceæ in India, and though the Lime, the Beach and the Chestnut extend from Europe to the Far East they avoid even the temperate belt of the Himalayas.

With the exception of the *Rhododendron* belt in the Himalayas the Pines of the north-west, bamboos locally in parts of Southern India and Burma and certain elements of the Xerophytic vegetation of the Indian desert, there are few assemblages of plants in India that characterize landscapes over wide areas. Palms in the lower areas of the peninsula, *Acacias* in many places, *Strobilanthes* as in the Nilgiris, *Dipterocarpus* as in the extreme east of our area and in Burma and Sal at the base of the Eastern Himalaya give a mark to the vegetation over considerable areas but they are far from taking the place of assemblages. They are at best conspicuous features of the landscape but not dominant. There is nothing for instance like the heaths of Britain or these and succulents in South Africa, the Eucalypti and Proteaceæ in Australia, the Cacti in America or the Aloes and Euphorbias of East Tropical and South Africa. The Prairies and Pampas of America have no corresponding assemblages here. The flora of the whole peninsula still strives, one member with another, and victory over wide areas to a gregarious species has yet to be established. We may even have to fix on certain plant immigrants of recent advent if we wish to illustrate the march of the struggle for supremacy. *Eichornea*, the water pest of Lower Bengal, now more than gives a distinctive feature to the landscape; *Lantana* is a widespread pest and *Croton sparsiflorus* shows signs of establishing itself to the exclusion of most else and in tracts of waste land. Of the same class but less objectionable than *Eichornea* are *Eupatorium odoratum*, *Ageratum*

conyzoides, *Mikania scandens*, *Argemone Mexicana*, *Suæda maritima*, *Opuntia Dillenii* and the lawn weed *Evolvulus nummularius* which is steadily increasing its hold. Quite a number of species of exotic *Oxalis* are now present amongst which *Oxalis corymbosa* tends to become a pest. The 'Flora advena' of India shows a marked number of species of American especially semi-tropical American origin. One naturally asks whether the opening of the Panama Canal has not had an influence on the floral elements that have within recent times established themselves here.

To leave the not truly Indian members and revert to groups of the indigenous flora we note that the Palms are less diverse in specific characteristics than they are further East or in the new world. The most conspicuous are the Talipot palms (*Corypha*) although not nearly so numerous as the Indian dates (*Phœnix*), or the Palmyras (*Borassus*) the Coconuts (*Cocos*) or the *Arecas* and *Livistonas*. These are mainly trees of the open plain or find themselves under cultivation. On the other hand, graceful erect or climbing palms with pinnate or fan shaped leaves frequent the humid evergreen forests where the Rattans (*Calami*) ascend the trees by their hooked spines and expose their feathery crowns to the light. More specialized and therefore more local, indeed locally dominant, are the all but stemless palms *Phœnix farinifera* of the Coromandal Coast, *Nannorhops Ritchieana* of North-Western India and *Phœnix paludosa* and *Nipa fruticans* of the Sunderbans. The last is estuarial and has a wide distribution. The Bamboos are nearly everywhere important. Well over a hundred species have been recognized by Gamble in his monograph of the group. They ascend from plains level to considerable elevations in most parts of India where the humidity allows of their development. They form, as elsewhere in the tropics, an important feature whether as clumps growing in the open or forming in association all but impenetrable jungle. They are the bugbear of the field botanist, for in addition to impeding his movement they shelter his most annoying enemies the ticks and the leeches. The taller kinds monopolize large areas in the hot lower regions, the smaller clothe mountain slopes up to 10,000 feet in the Himalayas. Of the endemic figs King has described 33 species and a multitude of others; they vary in size from small scandent and inconspicuous members like *F. scandens*, *F. macrocarpa*, *F. guttata*, *F. nigrescens* and *F. asperrima* to the spreading giants of the forest, *Ficus bengalensis*, *F. mysorensis* and *F. religiosa*.

Tree ferns of which there are comparatively few species and the Bananas of which more than are at present known seem likely to accrue to science, are comparatively local but yet conspicuous members of the vegetation.

The Conifers are almost entirely confined to the areas north of the great Indo-Gangetic divide. There are some 25 species of which a very few only are considered as not wild. Two species of

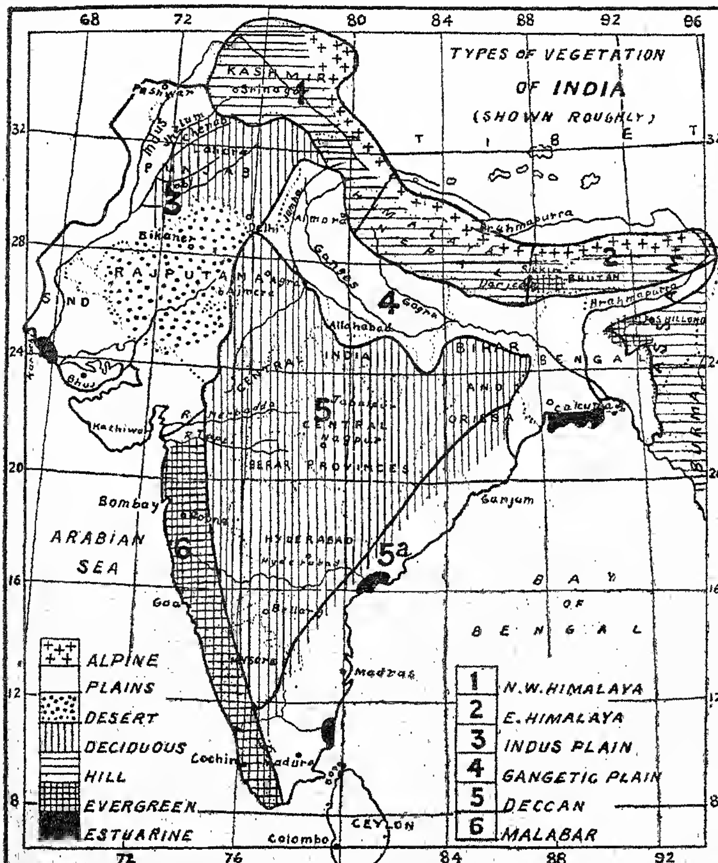
Juniper, a *Picea*, a *Taxus*, a *Tsuga* and a *Pinus* (*P. longifolia*) are common to the both ends of the range. *Agathis loranthifolia* and *Dacrydium elatum* are Malayan extensions and *Podocarpus neriifolia*, and *Pinus Merkusii* are more Malayan than Indian. *Juniperus communis* and *Taxus baccata* extend eastward from Europe, the latter to the Chino-Tibetan borderlands.

Types of Forest Vegetation of India.

The forest vegetation of India may be divided into five types; the evergreen, the deciduous, the dry, the hill and the tidal or littoral. The evergreen again is separable into two sections, that which comes under the influence of the main south-west monsoon and that, of the Carnatic, which depends on the much weaker winter or north-east rains. The former type occupies the west coast of the peninsula up to the ridge of the western mountain chain which cuts off the moisture laden sea winds from the Deccan and eastern portion of the peninsula. In the same way it is spread over the north-eastern part of the area with which we deal, and all the lower slopes of the Eastern Himalaya are characterized by it. It contains trees of many important families among which are specially noticeable the Dipterocarpaceæ, Guttiferæ, Annonaceæ, Meliaceæ, Burseraceæ, Sapotaceæ, Euphorbiaceæ and the Palmeæ. The evergreen forests provide in the main no exception to the rule of absence in India of a species dominant over a wide area; but some of its members, *e.g.*, Dipterocarps show nevertheless a tendency to the gregarious habit. They contain many species of great economic value and great size amongst which could be enumerated species of *Dipterocarpus*, *Hopea*, *Mesua*, *Calophyllum*, *Chickrassia*, *Cedrela*, *Dalbergia*, *Bischofia* and *Artocarpus*. Bamboos are plentiful and associated with them locally are to be found Teak, Rosewood and Ironwood. The Carnatic evergreens on the other hand are characterized by their comparatively smaller size and harder texture. Here we find the Ebony, species of *Mimusops*, the Jaman, the Neem and the Tamarind. The families Ebenaceæ, Sapotaceæ, Capparidaceæ, Rhamnaceæ and Myrtaceæ become prominent.

The deciduous type of forest occupies the larger part of the peninsula; it extends to Burma and is an important element in the Andamans. It is the most important from the forester's point of view containing as it does the main supplies of Teak (*Tectona*), Sal (*Shorea*) of the Sub-Himalayan tract, the Padauks and Red-woods (*Pterocarpus*), the Sandalwood (*Santalum*) of Mysore, Coimbatore and adjoining country and of Anjan (*Hardwickia*) the hardest and heaviest of Indian woods. Besides these, important species of the genera *Terminalia*, *Lagerstrœmia*, *Anogeissus*, *Soymida*, *Chloroxylon*, *Swietenia*, *Diospyros*, *Acacia*, *Albizzia* and others occur.

The dry forests are situated in Rajputana and the Punjab and spread over a large extent of native states. Towards the north and north-west they become richer and gradually blend into deciduous or alpine forests, whereas they get drier and drier towards



An outline map of India, showing Types of Forest Vegetation and Botanical Regions of India.

the west and south-west and disappear into the deserts on both sides of the lower Indus where the courses of perennial rivers alone are fringed by a belt of arboreous vegetation. The chief families represented in this region are the Leguminosæ, Capparidaceæ, Salvadoraceæ, Tamaricacæ and Rhamnaceæ, the most characteristic trees being the Jhand (*Prosopis spicigera*) and the various species of *Tamarix*, *Salvadora* and *Capparis*.

Hill forests are found within the Indian Empire along the whole of the Himalaya mountain chain from Assam to Hazara, and in the contiguous hill areas of Afghanistan, Baluchistan and Burma. In this belt the Coniferæ and Cupuliferæ find conditions for their development while other prominent families are the Sapindaceæ, Lauraceæ, Magnoliaceæ, Salicaceæ and Urticaceæ. Here flourish the Deodar (*Cedrus*), the pines (*Pinus longifolia, P. excelsa, khasya* and *Gerardiana*), the firs, *Abies Webbiana* ; the oaks include some six species while there are the Chestnut, Walnut, Maple, Elm, Ash, Birch, Poplar and Rhododendron.

The tidal or littoral forest type is situated along the moister part of the coast of India and especially in the deltas of its rivers. The prominent families of these forests are Rhizophoraceæ, Meliaceæ, Lythraceæ, Euphorbiaceæ and Sterculiaceæ and the chief timbers the Sundri, *Heritiera*, *Carapa*, *Avicennia*, *Sonneratia* and *Aegiceras*. The littoral forest is the home of the tidal palm Nīpa, the leaves of which are so much used for roofing purposes and the distribution of which in similar conditions extends eastward over a wide area.

The shrubby and herbaceous vegetation will be touched on in examination of the floral regions which follows, but the freshwater flowering plants may be briefly referred to now. Of all these the Nymphæas with their allies *Nelumbium speciosum* and *Euryale ferox* are easily the most conspicuous. In the moister parts of India and especially in areas where the water level maintains a perennial supply of moisture for their existence in shallower water they are to be found in abundance and associated with these are to be found *Pistia stratiotes* and species of *Lemna*. Of recent times and developing with such rapidity as almost to crowd them out, is to be found the water pest *Eichornia*, referred to above as exotic. The Podostemonads are among the most remarkable of India's freshwater flora. They clothe rocks and stones in rapid streams with submerged spreading fronds resembling green lichens more than flowering plants. A recent examination of this type of flora shows no fewer than 160 flowering species as ' common water or marsh plants ' ; the carnivorous bladder worts and, very rarely, the Venus Fly trap of southern Europe are both present.

The largest family of flowering plants in India is Orchidaceæ, with some 1,700 species, but the attractiveness of the family has prompted a fuller examination of its members than has been the case with others, and it is not improbable that monographs of other groups will at least diminish the numerical supremacy of the Orchids. Next in order of dominance come the Leguminosæ, Gramineæ, Rubiaceæ, Euphorbiaceæ, Acanthaceæ, Compositæ, Cyperaceæ, Labiatæ and Urticaceæ. Of these all but Labiatæ and Compositæ are more tropical than temperate. The low place of the Compositæ, the world's richest family of flowering plants, is remarkable. In most countries it heads the list. Here it comes seventh,

and if the Himalaya in its temperate and alpine zones be excluded from our area,—and indeed these zones are floristically not truly Indian—the Compositæ would disappear altogether from the list of ten dominant families. Its members are, as elsewhere, mostly herbaceous, rarely shrubby or tree-like. They are very seldom—*Artemisia* is an exception—gregarious. Monocotyledons in the Indian flora are relatively important, there being one for every seven species of Dicotyledons in spite of the fact that the Gramineæ as a whole are relatively weak. The Aroideæ on the other hand are well represented as are also the Scitamineæ and the Dioscoreaceæ.

The Botanical Regions of India.

The area with which we deal is primarily divisible into three botanical areas: a Himalayan, an Eastern and a Western. The prominent characters of the three are—that the Himalayan area presents a rich tropical, temperate and alpine flora with forests of Conifers, Oaks, Rhododendrons and a profusion of Orchids; that the Eastern has no alpine flora, a very restricted temperate one, few Conifers, many Oaks and Palms and a great preponderance of Orchids; that the Western has only one Conifer, no Oaks, few Palms and comparatively few Orchids. Further the Himalayan Flora abounds in European and Siberian genera; the Eastern in Chinese and Malayan; the Western in European, Oriental and African.

Climatic and physical conditions, however, admit of a rough division of India into six botanical regions, and an examination of the floral features of these will end this account.

These regions are the Eastern and Western Himalayas, the Indus plain, the Gangetic plain, Malabar and the Deccan, the two last in a very extended sense.

The Eastern Himalaya

The Flora of the Eastern Himalaya is well represented in Sikkim, the area which is botanically best known. This is the most humid district in the whole range. It contains over 4,000 species of flowering plants belonging to some 160 families besides 250 ferns and their allies, of which 8 are tree ferns. The ten dominant families of plants in order of numerical importance are Orchidaceæ, Gramineæ, Leguminosæ, Compositæ, Cyperaceæ, Urticaceæ, Scrophulariaceæ, Rosaceæ, Rubiaceæ and Euphorbiaceæ. Its flora may be conveniently examined in three altitudinal zones, a tropical, a temperate and an alpine, but it should be understood that there is no hard and fast line of demarcation between these, plants of the tropical zone reaching into the temperate and *vice versa*, and so with the temperate and alpine zones. Monocotyledons stand to Dicotyledons as 1 to 2·5, and as we ascend, the number of species tends to decline as does the density of the vegetation. Thus in the lower and middle zones there are respectively four

and three times as many species as in the upper; while the lower contains some 25% more than the middle.

The tropical zone which includes the gently rising plain at the foot of the hills is characterized above all else by its forests of Sal (*Shorea*) and by Leguminous trees (Plate I, bottom figure). There is a rich undergrowth of shrubs, coarse grasses and herbaceous plants belonging for the most part to the flora of the Gangetic Plain. Climbers abound from plains level upwards, there being representatives of all the chief climbing families—Ampelidaceæ, Cucurbitaceæ, Convolvulaceæ, Apocynaceæ, Asclepiadaceæ, Liliaceæ (*Smilax*), Dioscoreaceæ and Aroideæ, while herbaceous plants are well represented by Malvaceæ, Balsams, Orchids, Grasses, Aroids and especially in the rainy period by a profusion of Scitamineæ. Amongst shrubs the widespread prevalence of species of *Strobilanthes* in the forest is to be noted, whilst in clearings *Edgeworthia*, *Artemisia*, *Mæsa* and *Melastoma* seem to take their place.

There is a rich arboreal flora in this zone. The Magnolias reach profusion in its upper limit; Annonaceæ, Meliaceæ, Leguminosæ, Combretaceæ, Euphorbiaceæ, Urticaceæ, Rubiaceæ and Sterculiaceæ are present throughout. The presence of *Quercus* and *Castanopsis* and of the pine (*P. longifolia*) in this belt distinguishes its floral type sharply from that of the plains, but species of *Ficus* and *Sterculea* carry the similarity to considerable levels. Some 18 species of Palms are to be found; *Pandanus* is locally present to some height and Bamboos abound everywhere at the lower levels, there being some 12 different kinds.

In the temperate zone which may be said to extend from 6,000 to 11,000 feet the composition of the flora changes rapidly as we ascend. Numerical precedence is still retained by the Orchids, but a number of families which are of small importance at lower elevations here so greatly increase the number of their species as to prevail over the Leguminosæ, Euphorbiaceæ and Urticaceæ themselves. The Rosaceæ, Labiateæ, Ericaceæ and Umbelliferæ gradually reach importance in this zone to be themselves superseded at greater heights by more lowly if not less beautiful Primulas, Saxifragas and Crucifers. Of trees of the temperate zone the Magnolias—one species of which (*M. Campbellii*) formerly clothed the slopes round Darjeeling—are the most noteworthy; but the belt is characterized by Oaks, Laurels, Maples, Birches, *Alder*, *Bucklandia*, *Pyrus* and Conifers including the Silver Fir, the Yew, a Spruce and the only deciduous Conifer in the Himalaya *Larix Griffithiana* and especially by its wonderful Rhododendrons. As the cultivation of tea does not extend much into it, the vegetation in this zone retains more of its natural aspect than is the case in large areas of the belt below.

The alpine zone sees the complete exclusion of Orchidaceæ from the list of chief families. The Compositæ now come into

their own, and associated with them in order of importanco appear the Scrophulariaceæ, Primulaceæ, Saxifragaceæ and Coniferæ. The comparatively low position of the Sedges and Grasses is notable. One would have thought that the absence of canopy would have given these a chance at such heights. An explanation for the weakness may possibly lie in the depth of their root systems. But for a few Birches and Pyri that enter the alpine from the temperate zone trees would be entirely absent. Shrubby vegetation is represented by the Rhododendrons and Junipers and by species of *Ephedra, Berberis, Lonicera, Rosa* and *Cotoneaster*. An *Arenaria* which forms hard hemispheric or globose white balls is a characteristic feature of the landscape. But the most striking plants of the zone are species of *Meconopsis, Rheum, Primula, Tanacetum, Saussurea* and *Rhododendron*.

The Western Himalaya

Like the Eastern, the Western Himalayan botanical province can be divided into three roughly corresponding altitudinal zones, but the western province, considering its greatly extended breadth from south to north and therefore its much greater area, does not exhibit in respect of flora the degree of richness of the Eastern. The lower elevations of its south-eastern ranges display, however, general floral features not unlike those of the Eastern province. Taken as a whole the western area is botanically far better explored and yet the number of species in the whole of the known western area only equals the number in the comparatively small section taken as representative of the Eastern zone. In this province the Orchidaceous species recede from first place to seventh in the order of numerical importance. The cold loving and better drought resisting members of the families Gramineæ, Compositæ and Leguminosæ now head the list, while in comparison with the Eastern Himalaya the Labiates, Ranuncules and Crucifers gain markedly in importance. Bulbous plants predominate and Monocotyledons gain over Dicotyledons when comparison is made with the proportion in the East. The Vacciniaceæ, which represents a temperate or sub-alpine group of plants, curiously disappears in the West; but so also do the tropical Dilleniaceæ, Guttiferæ, Passifloraceæ, Myristicaceæ, Cycadaceæ, Burmanniacoæ and Pandanaceæ. Against their disappearance is to be placed the advent of such groups as the Resedaceæ, Moringeæ, Polimoniaceæ and Salvadoraceæ. An examination shows that of typically European elements there are twice as many in the western as in the eastern Himalaya, the presence of saline soil in the west accounting especially for the tremendous predominance in respect of Chenopods. Palms come down to six, including 3 species of *Phœnix*, against three times as many in the East. The occurrence in the North-West of the curious stemless *Nannorhops Ritchieana* has already been noted in references to the gregarious habit in the Indian Flora (Plate I, top figure). The tropical type of flora dies out rapidly as the extreme north-west portion of the province is

reached, but certain tropicals are yet found here that are absent from the Eastern province. Among these the true *Pistacia*, the Pomegranate and the Oleander are noteworthy. Bamboos practically disappear.

The temperate zone of the Western Himalaya is more hospitable than the Eastern to Conifers. All members present in the East, except the Larch, extend westward, but there get added forests of *Pinus longifolia*, *Abies Webbiana*, *Cupressus torulosa*, Junipers and *Pinus Gerardiana* (Plate II, bottom figure). Within temperate conditions oaks are more accommodating, the numbers in the east and the west more nearly equalling. *Quercus Ilex*, the Holm oak, fails to reach Sikkim but is present in the West.

Shrubs peculiar to the West are the Indian Bladder-nut, (*Staphylea*), the Lilac (*Syringa*), several kinds of Roses, the Mountain Ash, *Pyrus*, and the Hawthorn (*Cratægus*). But the chief difference lies in the greatly reduced number and importance of the Rhododendrons. Several Ranunculaceous herbs, unknown in the East, are here present together with species of *Aquilegia*, *Pæonia*, *Adoxa*, *Eriophorum* and many Grasses, Rushes and Carices. Balsams abound at all elevations in the temperate zone except the highest, the species being with few exceptions endemic. As is to be expected the decrease of rainfall as the Western Himalaya is reached results in a diminution of epiphytic vegetation, a fact emphasized by the relative preponderance in this zone of terrestrial, as against epiphytic, Orchids. Palms are confined to one species, *Trachycarpus Martiana*, and Bamboos to four dwarf gregarious.

The alpine zone abounds in Astragali and the prevalence of Artemisias, Saussureas, Tanacetums and others accounts for Compositæ taking first place here as it does in the corresponding zone of the Eastern Himalaya. Grasses and Legumes gain prominence as also curiously enough does the Gentians, a group one might think to predominate in the East with its Chinese element. Two conspicuous eastern alpines *Rheum nobile* and *Tanacetum gossypium* disappear although Arenarias carry on throughout the range at the higher elevations.

The Indus Plain

The Indus Plain province includes the Punjab, Sind and Rajputana west of the Aravalli range and Jumna river, Cutch and Gujarat. The forest flora of much of this region is fully described by Parker. Sal finds its extreme western limit in this province. The principal trees of the Indus Plain are *Bombax malabaricum*, *Sterculea urens*, *Moringa* spp. *Boswellia serrata*, *Odina wodier*, *Aegle marmelos*, *Pistacia integerrima*, *Prosopis spicigera*, *Acacia* spp. *Dichrostachys cinerea*, *Dalbergia* spp. *Mimosa* spp. *Anogeissus pendula*, *Cordia* spp. *Tamarix* and *salix*. Except, however, towards the lower levels of the Himalayas, on the slopes of the Aravallis and where irrigation allows of the development the forests are stunted and tend more to scrub. Saline tracts characterize the province over wide areas; here

species of *Salsola* and the Arabic grass, *Sporobolus* thrive, elsewhere the odorous *Andropogon jwarancusa* and *A. nardus* and among trees *Acacia arabica, Tamarix articulata,* and *Butea frondosa* are said to stand the saline conditions well. Along the rivers *Tamarix dioica* is the commonest woody plant along with *Populus euphratica,* but *Acacia Farnesiana* is naturalized and *Dalbergia sissoo* is commonly planted. Compared with the adjoining Western Himalaya the flora is poor and is naturally adapted to the semi-desert conditions, for whether we proceed across the province in a south-west direction from the Himalaya to Sind or in a south-east direction from the Afghan border to western Rajputana vegetation rapidly diminishes, approaching extinction in the Indian desert. Irrigation in the Indus Plain province has greatly affected the natural flora. The chief families of plants are still those that take precedence in the Western Himalaya, the Gramineæ, Leguminosæ, Compositæ and Cyperaceæ heading the list in both provinces, but the number of species in the plain is only about a third of that in the Western Himalaya. Shrubby vegetation as is to be expected largely takes the place of trees and among the herbaceous there is a strong element of the annual type or of vegetation that can withstand prolonged periods of drought. The most conspicuous shrub is the Xerophytic *Euphorbia Royleana* but *Capparis, Zizyphus, Grewia, Balanites, Calotropis, Alhagi, Cassia, Dodonea* and *Calligonum* are genera represented and are all prevalent (Plate II, top figure). *Gossypium Stocksii,* the only indigenous cotton of the old world, is confined to Sind.

The deltaic vegetation of the Indus resembles that of the Sunderbans but is much poorer in species, one of the main elements in the East, *Nipa fruticans,* being absent in the West as is also *Phœnix paludosa.* The only Palms of the Indus Plain are the wide-spread *Phœnix sylvestris* and the local gregarious *Nannorhops Ritchieana* the presence of which is indicative of dry sandy conditions. Besides in Sind the latter finds conditions favourable for its development in the Salt Range. The hardy Bamboo, *Dendrocalamus strictus,* is the only natural representative of its class in the area. The whole area attracts the physiological botanist and the ecologist rather than the systematist.

The Gangetic Plain

The Gangetic Plain botanical province has through the influence of man in the course of untold generations lost much of its primeval appearance. It is agriculturally the richest part of India and is now to a very great extent given over to cultivation. With the exception of the Sunderban part the flora, therefore, is not now what it came from or what it would revert to if the hand of man were removed. There are records of its being covered at one time by vast forests of Sal which have now all but disappeared except on the slopes and at the base of its mountain boundaries. It is geologically of recent origin having been formed in the course of

ages by the silt of the Ganges and its tributaries which may at one time have linked with the Indus System. Botanically it is not a single province: it would, indeed, even when the sloping hill tracts to its sides are excluded and still more when they are included, be better to treat it as three provinces. There is the flora of the Upper Gangetic Plain, between which and those of the Indus Plain the middle Himalayas and the Deccan there are marked affinities, the flora of the middle plain represented by the vegetation of Bihar and Orissa and Western Bengal and the flora of the lower plain or deltaic area typified in the Sunderbans. As the province has been well explored and shows itself divisible into three botanical sections it will be well to treat it so. The Upper Gangetic Plain includes all that country drained by the Ganges and its north and south tributaries from the edge of the rising country north-west of Delhi to a roughly north-south line running through Benares. The indigenous vegetation in its western part is that of a dry country, the trees in the dry season being for the most part leafless and the grasses and other herbs burnt up; but by far the greater part of the land to the eastward contrasts with that to the west in being under cultivation. The flora of the western extreme as indicated by such species as *Peganum harmala*, *Pluchea lanceolata* and *Tecoma undulata* is continuous with the dry districts of the Indus Plain. The principal forest is that of Ajmere characterized by *Anogeisus pendula* and by species of *Boswellia*, *Balsamodendron*, *Moringa*, *Rhus*, *Acacia* and *Prosopis*. The Bengal rose occurs and in the cold season the area is characterized by a herbaceous annual flora in which many English species are to be found. Bamboos, unless where planted and tended or on the borders of the hills, are almost absent, but the Date Palm locally over the area and a few species of Rattans in the submontane thickets represent the Palms. *Salvadora* characterizes the so-called Reh-lands impregnated with their alkalis. The absence of Guttiferæ from the area is noteworthy, but this is only one family of a list of absentees that are yet present in the districts north, south and west of the Upper Plain. Leguminosæ, Gramineæ, Cyperaceæ and Compositæ occur in order of prevalence. Savannah or grass lands sometimes of considerable extent occur and are dotted with trees like *Bombax malabaricum*, *Randia uliginosa*, *Butea frondosa* and *Zizyphus* sp. (Plate III, bottom figure). The Middle Gangetic Plain takes in all the country to the east of a north-south line through Benares and includes the plains of Assam. It is the evergreen country of India in which cultivation has *par excellence* affected the flora. A huge sea of waving rice fields extending as far as the eye can reach now best characterizes it. The villages are buried in groves of mango, jack fruit, betel nut, figs and palms, and amongst the herbaceous vegetation the Aroids both wild and cultivated are conspicuous. Broad tanks take the place of the wells of Upper India and in these the lotus Nymphæas and all the

pond vegetation referred to above is to be found. This type indeed probably best represents the original flora of the Middle to Lower Gangetic Plain for it has been least interfered with by the hand of man. In the eastern portion where the waters of the Ganges and Brahmaputra tend to overflow, the jhils or side canals and old river beds are characterized by a luxuriance of marsh grasses and Cyperaceæ, typified by tracts of *Saccharum spontaneum*. Among the trees many are introduced *Bombax, Polyalthia, Eriodendron* spp. and even such common species as *Poinciana regia* (the gold mohur) *Lagerstroemia flos-regina, Pterospermum acerifolium, Casuarina equisitifolia* and *Artocarpus integrifolia* are of this kind. In the drier districts the Babul, *Acacia arabica*, is a characteristic feature. For a full account of the Sunderbans flora which together with the flora of Sikkim, visitors are likely to have a chance of inspecting, a reference is invited to Prain's works. This flora is notable from the fact that, considering the limited area occupied, it contains more local species than does any other botanical area in India. This is to be ascribed to the peculiarity of its soils being saline and to its receiving a more than ordinary share of the south-west monsoon rains.

The Sunderbans.—The Sunderbans are clothed with a dense evergreen forest of trees and shrubs and constitute, therefore, an important forest division. Typical of the Mangrove forest which takes precedence are species of *Rhizophora, Carapa, Ceriops, Bruguiera, Sonneratia, Aegiceras,* and *Avicennia* (Plate IV, bottom figure). A remarkable character in this vegetation is the habit of several of the endemic species to send up from their subterranean roots a multitude of aerial root suckers which act as respiratory organs. In some places these may become so numerous that passage through the forest is difficult. They act like a small forest of spikes jutting out from the ground. Two Palms of the Sunderbans deserve special attention, *Nipa fruticans* and *Phoenix paludosa.* The former covers considerable areas in great stretches of the tidal regions both here and further east, a palm taking almost complete possession of the borders of the estuaries where the conditions are brackish but declining waters that tend to become fresh (Plate IV, top figure). Repeated attempts to introduce it to the relatively sweet water of the Royal Botanic Gardens at Sibpur have been made but it always dies out. *Phoenix paludosa,* on the other hand, thrives in the drier localities. In addition to the Mangrove type we have, however, many Sunderbans species common to inland Bengal, *e.g., Pongamia glabra, Kleinhovia hospita, Agle marmelos, Odina wodier, Cordia myxa, Streblus asper,* and *Barringtonia acutangula* being representatives of trees common to both. With the Mangrove is mixed Typhaceæ, Gramineæ and Cyperaceæ. As in the rest of the Gangetic Plain province the families Leguminosæ, Gramineæ and Cyperaceæ still stand out as including the largest numbers of species, but here the Orchidaceæ, in contrast to the upper sections of the plain, begin to

creep up the list of dominant families. There are some 13 species, all, however, epiphytic, a sign of the increased humidity of the atmosphere. It is curious that while the grasses are plentiful no species of Bamboo has been able to accommodate itself to the wet saline conditions. Amongst the undershrubs two species of *Acanthus* are prominent with their light blue flowers and holly-like leaves.

Malabar

From the humid character of the Malabar climate its luxuriant vegetation might be inferred (Plate III, top figure). In verdure it resembles the eastern part of the Gangetic Plain and most deltaic regions, but it has loftier trees and more palms: the shores are skirted with Coconuts, and the villages surrounded with groves of Betel-nut palms and Talipots, while *Vateria indica*, a noble Dipterocarp tree, is abundantly planted in many parts. Cassia and Cardamoms flourish wild in the jungles and the fact that Pepper can be cultivated without the screens used in other parts of India to preserve the humidity, conveys an idea of how naturally moist the coast region is. It is impossible to demarcate the Malabar region in a botanical sense from the Deccan, for the mountains of the Ghats project sometimes far inland and carry a flora characteristic of the west well into an area that is geographically Deccan. It is one of the botanically richest areas in India. The mass of the flora is Malayan and identical with that of Ceylon, and many of the species are further common to Khasia and to the base of the Himalaya. Teak is abundant but Sandal wood occurs only in the east and dry flanks of the ghats. The Cupiliferæ and Coniferæ are wholly unknown in the west. The most distinctive characters of the Malabar flora, in contrast with that of the Deccan, are primarily the excessive content of Guttiferæ, Dipterocarpaceæ, Palmæ, and Bambuseæ and secondly the great prominence of the Malayan type represented by Sterculiaceæ, Anacardiaceæ, Meliaceæ, Myrtaceæ, Melastomaceæ, Scitamineæ, Orchidaceæ, Aroideæ and others. As the visitor may possibly wish to see the Nilgiris and as this range forms part of the mountainous backbone discussed under Malabar a few notes on it may be of interest. The ravines and shady slopes near the undulating summits are occupied by thickets of small trees and bushes like those of Ceylon and they are equally characteristic of similar situations in the Khasia mountains. These mountains form a noeud of the Western Ghats where they attain their greatest elevation of 8,760 feet. They rise precipitously from the west to extensive grassy downs and table lands seamed with densely wooded gorges locally termed "Sholas". The "Sholas" are filled with evergreen forest, some of the most conspicuous trees being *Michelia nilagirica*, *Ternstroemia japonica* and *Gordonia obtusa* and species of *Ilex*, *Meliosma*, *Microtropis*, *Euonymus*, *Photinia*, *Viburnum*, *Eugenia*, *Symplocos*, *Glochidion* and *Araliaceæ* and Lauraceæ are all present.

Of shrubs *Strobilanthes* take first place. It is from these that the mountains get their name, the expanses of their blue flowers

being responsible for the term Nilgiris. Next come species of *Eurya*, *Ligustrum* and *Vernonia*. Of climbers we have *Rosa Leschenaultiana*, *Jasminum brevilobum*, *Gardneria ovata*, *Gymnema hirsutum* and *Elæagnus latifolia*. Amongst conspicuous herbs the genus *Impatiens* is a notable feature while at lower elevations in the "Sholas" *Hydnocarpus alpina* and a *Rhododendron* and *Vaccinium* stand out. Bamboos are rarer at these heights than is the case at similar heights in the northern ranges, but a Ceylonese bamboo *Oxytenanthera Thwaitesii* is found and also an *Arundinaria*. An analysis of the floras of the Nilgiri and of the distant Khasia, Manipur and Naga hills shows a striking affinity between the two. This is the more remarkable that the floras of intervening ranges of mountains do not form satisfactory connecting links. Peat bogs, which are of the rarest occurrence in India, are found in depressions of the Nilgiri Hills towards their summits. The peat is composed, as elsewhere, of Grasses, Sedges, Mosses and Rushes and the bogs are the location of the curious Ceylonese *Hedyotis verticillata* besides of species of *Utricularia*, *Eriocaulon*, *Exacum* and *Commelyna*. An exotic element in the form of Australian gums, which are widely planted, must strike every visitor to the Nilgiris.

Deccan

The whole peninsula south of the Ganges Valley and east of the Malabar Ghats is characterized by a plateau of medium height from which rise in an west-east direction spurs from the Western Ghats and through which flow eastward a series of rivers the Godavari, Krishna and Cauvery and others draining into the Bay of Bengal. These rivers have eaten more or less broad sections out of the plateau and up these sections where cultivation has not disturbed the natural vegetation, is to be found a flora more characteristic of the Indian plains, especially the western, than of the Deccan in its true sense. The plateau terminates in the east in a lower range of hills, the Eastern Ghats, the flora of which is still mainly Deccan, but from here to the sea the land falls more or less abruptly into what may be called the Coromandal Subprovince with a flora distinct in important respects from that of the true Deccan. Over the Deccan province deciduous forests are the most conspicuous feature of the plateau and comparatively evergreen ones on the coasts and slopes with an eastern aspect. The Sal (*Shorea*) finds its natural southern limit near the Godavari, but the Teak (*Tectona*) occurs at intervals over the whole Deccan area. The Northern Deccan is floristically linked with the temperate to subtropical floras of the Eastern and Western Himalayas. Here are still to be found for instance species of *Thalictrum* and *Berberis* and it is moist enough for the epiphytic Orchids and for such species as *Lasianthus laurifolius*, *Pygium acuminatum*, *Dysoxylum procerum*, *Ardisia depressa*, *Bielschmiedia fugifolia* and *Cyclostemon assamicus*, species that show special affinity with the floras of the humid districts of Assam and Burma.

Of Deccan forest trees there are several hundred species, amongst which Sterculiaceæ, Meliaceæ, Leguminosæ, Combretaceæ, Bignoniaceæ and Urticaceæ are well represented. The Satin wood (*Chloroxylon*), *Chikrassia*, the Indian Red wood (*Soymida*), and the Toon (*Cedrela*) are all important, but the best known is probably the Odoriferous Sandal-wood forests of which are to be found in Mysore and adjoining districts. *Butea frondosa*, so common in the plains and uplands to the south of the Indo-Gangetic flat, and *Cochlospermum gossypium* both trees characteristic of areas with marked seasonal variations are common throughout, and the same seasonal characteristic is accentuated in the prevalence of such shrubby vegetation as *Capparis*, *Grewia*, *Flacourtia*, *Diospyros*, *Flueggia* and *Phyllanthus*.

The herbaceous vegetation has a negative distinction in the relative absence of epiphytic Orchids and of Scitamineæ, groups that demand shade or all but permanently humid conditions, but the common annuals or perennials of the Gangetic Plain extend southward into a great part of the Deccan and prominent in the herbaceous class are Acanthaceæ, Commelynaceæ, Gramineæ and Labiatæ. The chief Bamboos are the common *Bambusa arundinacea* and *Dendrocalamus strictus* and of Palms the commoner dates are *Phoenix sylvestris*, *P. acaulis* and *P. humilis*, the Tal or Tar *Borassus flabillifer* and some Calami.

Mysore, Carnatic and Coromandal.—The vegetation of Mysore, which comes within the use here made of the term Deccan, may possibly call for special remarks as this State may be visited. The vegetation here like that of the Carnatic further south is somewhat scanty. The table land is often barren and the hills at best covered with a low shrubby vegetation. But towards the west, where the influence of the monsoon is felt, the vegetation tends to be similar to that of the Western Ghats, the Malabar type, and considerable forests are therefore found. The steep slopes of the Eastern Ghats which come normally within the influence of the north-east monsoon are also densely wooded, species of *Dipterocarpus*, *Pterocarpus*, *Acacia*, *Butea*, *Lagerstroemia*, *Terminalia*, *Nauclea*, *Diospyros*, *Tectona* and *Santalum* predominating. Few palms are indigenous, except in the dense western forest, but all the commoner ones are found in cultivation. The black cotton soils, which prevail over large areas in the Deccan, are characterized by an assemblage of indigenous plants among which the following trees figure : *Capparis divaricata*, *Acacia arabica*, *Prosopis spicigera*, *Parkinsonia aculeata* and *Balanites Roxburghii*. Shrubs are *Cadaba indica*, *Zizyphus nummularia*, *Cassia auriculata*, *Calotropis procera*, and *Jatropha glandulifera* and herbs *Hibiscus trionum*, *Momordica cymbalaria* and *Cressa cretica*. The Coromandal Subprovince carries the Deccan type of flora to the sea. Mangroves occur in the estuaries. Elsewhere thickets of thorny evergreen and deciduous trees and shrubs abound, but at its southern end the influence of the north-east monsoon is

lost and this part is hot and dry. It is characterized by the umbrella shaped *Acacia planifrons* and by the best Indian Sennas (*Cassia*).

Towards the north tracts of Nuxvomica and of Ebony are now economically important and the sandy soils of the coast are characterized by the uprooted masses of *Spinifex squarrosus*, a grass distributed by the wind. One introduced plant, *Opuntia*, is now, it would seem, more under control than it used to be.

EXPLANATION OF PLATE I.

FIG. 1.—S.-E. of Boya Fort, Waziristan.

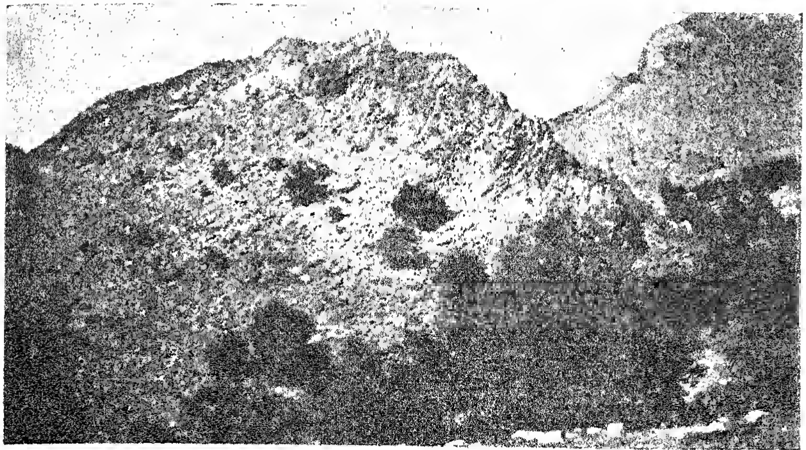
At the base *Nannorhops ritchieana* H. Wendl. Large trees of *Olea cuspidata* Wall. and *Monotheca buxifolia* Dcne. Small bushes of *Withania coagulans* Dunal.

Reproduced by courtesy of Bombay Nat. Hist. Society.

FIG. 2.—Portion of a *Sal* Forest, Darrang Forest Division, Assam.

Reproduced from *Indian Forester*, Vol. XLIII, (1917).

CALDER: *The Vegetation of India.* PLATE I.



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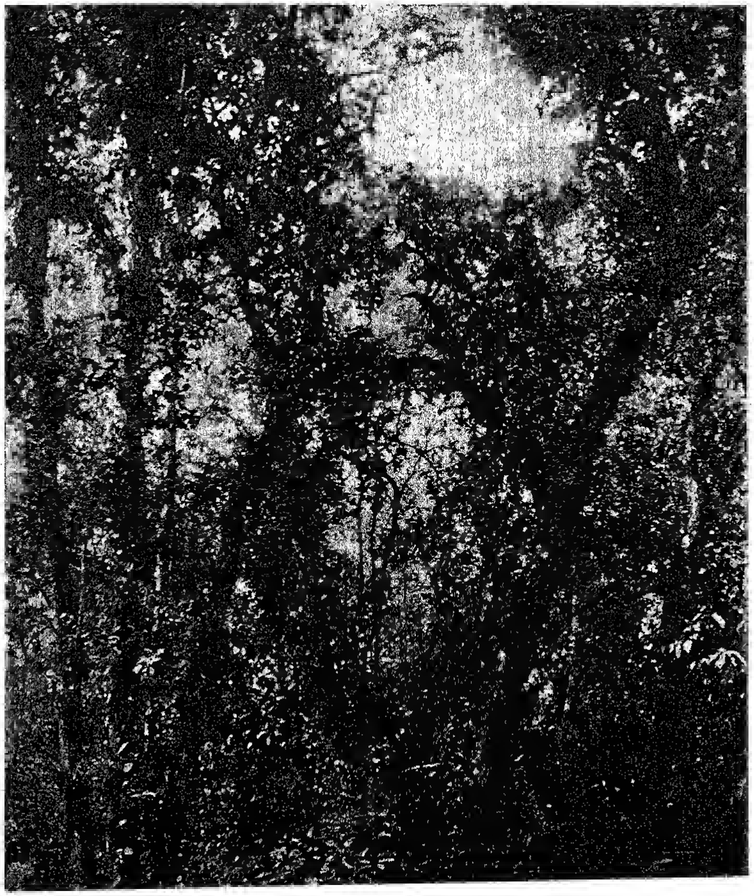
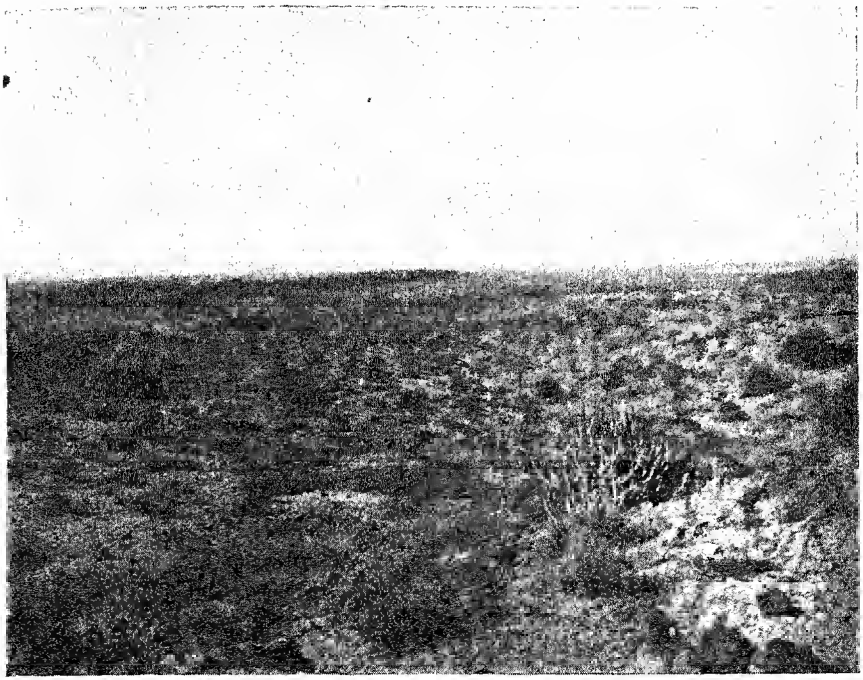


EXPLANATION OF PLATE II.

FIG. 1.—Typical desert vegetation in Sind.

FIG. 2.—Himalayan scenery at the edge of the tree line.

Both illustrations reproduced by courtesy of Bombay Nat. Hist. Society.



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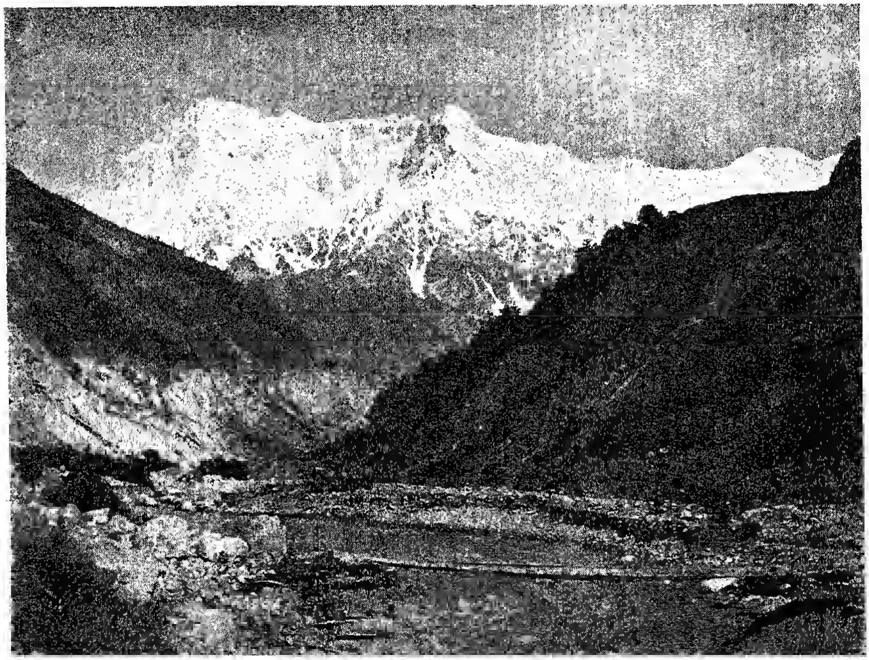


EXPLANATION OF PLATE III.

Fig. 1.—Typical moist evergreen forest, Thattā Kād, Travancore.

Reproduced by courtesy of Bombay Nat. Hist. Society.

Fig. 2.—A portion of the bed of the Tons River below Jhajra. The sandy deposits on the banks of these large streams constitute an extensive savannah of *Saccharum Munja*.

Reproduced from *Indian Forest Memoirs*, Vol. I, (1911).

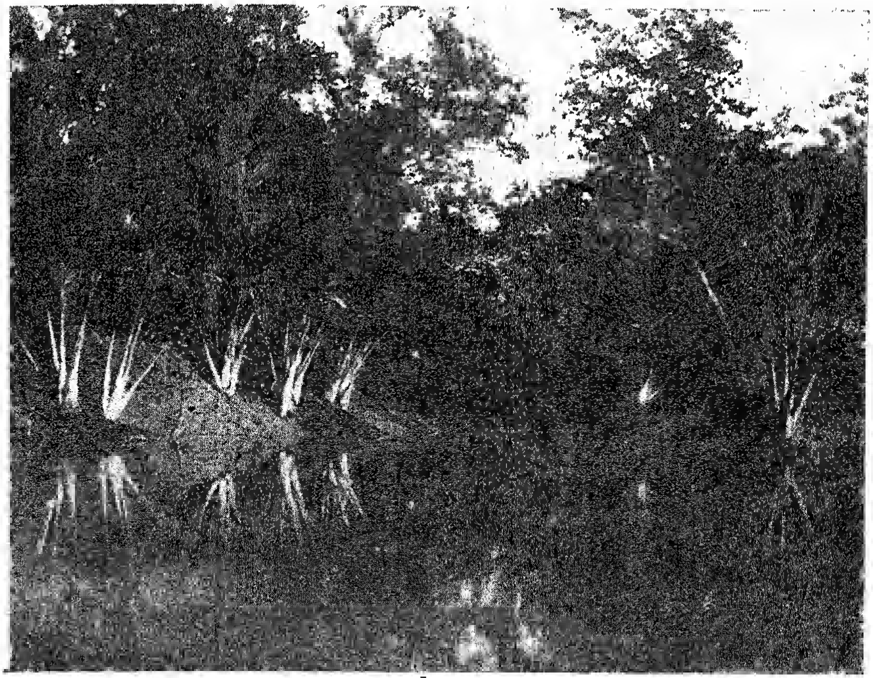
1.

EXPLANATION OF PLATE IV.

FIG. 1.—A scene in the Sunderbunds at low tide.
A small river giving access to the interior of the jungle, and small palms growing out of the mud.

FIG. 2.—Malancha River during high tide, South Sunderbunds near the sea.

Both illustrations reproduced by courtesy of Bombay Nat. Hist. Society.



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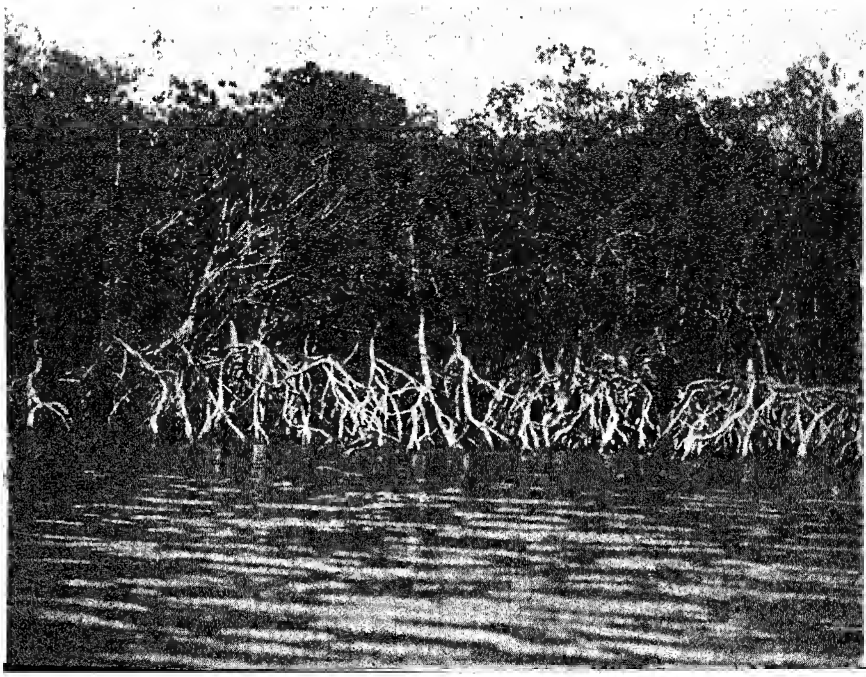

AN OUTLINE OF THE FAUNA OF INDIA.[1]

By

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Contents.

Introduction.

The animal populations of India are infinitely more varied and colourful than its human populations with their innumerable tribes, castes, customs and languages. India is a land of contrasts with its varied physical and climatological features. It has some of the loftiest mountain ranges and low hills and plateaux, impenetrable evergreen forests and scrub-jungles, hill-streams with torrential falls over precipitous rocks, and broad and long placid rivers with their extensive deltaic and estuarine systems, rich alluvial plains stretching for hundreds of miles, and sandy wastes, deserts, and uncultivated open tracts of land, lakes, tanks and backwaters, and marshy, sandy or rocky coasts. The regular monsoons with their well-marked paths distribute their favours unequally so that there are regions of very heavy to moderate rainfall and of rainless

[1] In the preparation of this Outlino the author has found the following works and journals of great help: 1. *Fauna of British India,* 2. *Imperial Gazetteer of India,* Vol. I, 3. *Journal of the Bombay Natural History Society,* 4. *Journal and Memoirs of the Royal Asiatic Society of Bengal,* 5. *Records* and *Memoirs of the Indian Museum,* 6. *Bulletins of the Madras Government Museum* and the *Madras Fisheries Department,* and 7. Alcock's '*A Naturalist in Indian Seas*'.

tracts. Parts of the country in the higher latitudes are subject to extremes of temperature, while those of the lower latitudes have a relatively more uniform climate. Elevations of the land in both the latitudes or the proximity of the sea tend to modify the severity of the climate to a considerable extent. The character and distribution of the animal communities in India are, therefore, to a large extent dependent on the physical and climatological features of the country. It must be remembered, however, that the past geological history of the Indian sub-continent and its adjacent land masses has played a considerable part in determining the character and distribution of the present fauna.

With a rich and varied fauna such as India has, any attempt to give a general sketch of the fauna characteristic of India as a whole would be attended with little success. The Indian sub-region of the Oriental Region is overlapped by other zoological regions in its outlying parts resulting in the penetration of certain elements of the fauna from the latter regions into the outlying areas of the former. Thus the Eastern Himalayas, Assam and Burma which form the eastern portion of the Indian Empire have an Indo-Chinese and Malayan element in it, while the north-western part, including the W. Himalayas, the Punjab, Kashmir, W. Rajputana, Sind and Baluchistan, has a predominant Palæarctic element. The S.W. of India, also known as the Malabar Region, and S.W. Ceylon have a closely similar and characteristic fauna which is rich in individuals and endemic species.

The study of Zoology as a field science in India may be said to date back to the 17th and 18th centuries. To those interested in the historical aspect of field Zoology in India the admirable account of this subject given by Gravely (1922) would be valuable [1]. Within the last 25 years much of the field work done in India was officially sponsored by the Government of India, and unofficially by the Bombay Natural History Society among others. Expeditions such as those organized by the Cambridge University, the Yale University of the United States and others to study the field aspects of Zoology in India have been the exception rather than the rule. The Universities teaching Zoology in India are taking an increasing part in the exploration of local fauna thanks to the interest inculcated in post-graduate students for research work. But in recent years the progress of field Zoology under official auspices has suffered a set-back in India owing to the severe curtailment of Government grants to promote field work. Marine zoological survey work which started so well on the Royal Indian Marine Survey steamer 'Investigator' in the last quarter of the 19th century and flourished till 1925 has suffered similarly, first as a result of the world war, and lately as a result of the general financial stringency in the country since 1931.

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[1] *Proc. As. Soc. Bengal* (N.S.), XVII, pp. cxxxii–cxlvi (1921).

In the short space available for this Outline on field zoology it will be difficult to give an adequate account of both the Vertebrate and the Invertebrate fauna of the Indian Empire. The Birds amongst the former, and the Insects among the latter have attracted much attention because of their great variety and common occurrence in various situations all over the country, and the fact that the number of volumes dealing with these groups of animals in the *Fauna of British India* series which have hitherto been published far exceeds that of volumes devoted to all other groups of animals dealt with in the series is an indication of their wider appeal to naturalists and others. The depredations caused by wild animals, and insect and other pests to crops and human beings and the interest evinced in blood-sports by certain classes of people in India have stimulated the accumulation of much knowledge of the beasts of forest tracts and lesser jungles. A consideration of the relatively better known Vertebrate animals of the Indian Empire should more appropriately precede an account of the Invertebrate fauna which will be dealt with in relation to the types of environment common in the Empire and the animal communities characteristic of them. Although the work of the 'Investigator' (now of the Royal Indian Navy) in the Indian seas has revealed a wealth of interesting deep-water forms the account of the marine fauna in this outline is confined to that of the sea-beach between tide-marks and at a depth not exceeding one fathom. The fauna of the estuaries, lagoons and backwaters on the various Indian coasts are more or less of the same type with an admixture of animal forms that are of marine as well as brackishwater origins. The fauna of the fresh-water systems in the different parts of the Indian Empire includes species and genera which are of very wide distribution in the Oriental Region, but the few relict marine elements which are present in the rivers and lakes of India and Burma indicate the distribution of land and water in recent geological periods and the trend of migration of marine animals. The animal communities that have established themselves in caves, hill-streams, estuaries and desert tracts show considerable powers of adaptation which their congeners in other localities lack.

MAMMALIA.

Within the Indian Empire the Mammals are of very great diversity in form and habits. Certain groups of Mammals do not at all occur within Indian limits. Amongst these are the Duckbill and Spiny Ant-eater (Monotremata), and the pouched Mammals such as the Kangaroo and the Opossum (Marsupialia). The Camel, the Giraffe, the Zebra, and the Hippopotamus amongst the Ungulates, and the Seal and the Walrus amongst the Carnivora do not belong to the Indian fauna. The Mammals characteristic of the Indian Region are discussed below :—

Primates

Among the Primates the Monkeys are the best known in India, being represented by several species common in different parts of the country. The Simian Apes are represented by two species of Gibbons of the genus *Hylobates* which are found in the forests of Assam and Burma in large parties. The best known Monkeys are the long-tailed Bonnet Monkey (*Macaca radiata*) of South India and the short-tailed *Macaca mulatta* of Northern India, both of which are trained as performing monkeys by mountebanks. The Langurs or Hanuman Monkeys (*Pithecus entellus*) with longer limbs and tails are of legendary fame being connected with the story of the Hindu epic, Ramayana.

The Lemurs are not so well represented in India as in Madagascar. The Slender Loris (*Loris lydekkerianus*) living in the forests of South India and Ceylon, and the Slow Loris (*Nycticebus coucang*) living in the forests of Assam and Burma are the best known representatives of this group.

Carnivora

The terrestrial Carnivores of the Indian Empire include: (1) the Cat group, consisting of the cats, civets, mongooses, and hyaenas, (2) the Dog group, consisting of the dogs, jackals, wolves, and foxes, and (3) the Bear group, consisting of bears, badgers, martens, weasels and racoons. No true aquatic Carnivore occurs in the Indian Region.

The Cat-group : Large Cats.—The Indian Lions (*Panthera leo persica*) were, within historic times, found in North and Central India, but at the present day they occur only in the Gir Forest of Kathiawar peninsula covering an area of about 500 square miles of rugged undulating country of stunted trees, bamboo, and thorny shrubs and bushes. They are protected by game-laws within the Junagadh State of Kathiawar. The Tigers (*Panthera tigris*) live in India under varying environmental conditions such as the winter snows of the Himalayas up to an altitude of 10,000 ft., the humid ever-green forests, the dry open jungles, and the swamps consisting of grass and trees. They are absent from Ceylon where their place is taken by the Panthers. Of these latter (*Panthera pardus*) there are three races and varieties in the Indian Region differing in the colour and texture of the fur coat, *e.g.*, the Kashmir Panther (*Panthera panthera millardi*), the Sind Panther (*Panthera panthera sindica*) from the barren Kirtar hills of the Sind-Baluch frontier, and the Indian Panther (*Panthera panthera fusca*) whose range extends from the Himalayas to Cape Comorin and Ceylon. They thrive equally in the humid rain-swept forest and in the dry treeless tracts. The beautiful Snow-Leopard (*Uncia uncia*) is an inhabitant of the Himalayan ranges at altitudes varying from 6,000 to 18,000 feet above the sea level. The Cheetah or Hunting Leopard (*Acinonyx jubatus*) is almost extinct in the wild state, although it had once a wide range in the plains of North India. It is usually

found in low rugged country bordering the plains amongst rocks and boulders.

Small Cats.—The typical Cats (Felinæ) are represented in India by a number of small and medium-sized forms. The common Wild Cat of India, the Jungle Cat (*Felis chaus affinis*), is found in the drier parts of the Indian Empire where grass, scrub, or reeds abound, while the Desert Cat (*Felis ornata*) is found in the deserts and arid parts of N.W. India and in the eastern parts of the Central Province. The true Lynx (*Lynx lynx isabellina*) occurs in the Indus valley and Ladak, while the Caracal (*Lynx caracal*) or Siyah Gosh which is trained to hunt is common in the desert and scrub jungle of Sind, Cutch, and the drier parts of the Punjab, Rajputana, United Provinces, and Central India. The Leopard Cat (*Prionailurus bengalensis*) is an inhabitant of the ever-green or mixed forests of India and Burma while the Rusty-spotted Cat (*Prionailurus rubiginosus*) is common in the hill-forests and jungles of South India and Ceylon. The Fishing Cat (*Prionailurus viverrinus*) lives in heavy forests, scrub jungle of the Himalayan foot-hills, Ceylon and Burma, in grass swamps and reed-beds of rivers and tidal creeks of Bengal, United Provinces and Sind, and in the backwaters of the Malabar coast. The Marbled Cat (*Pardofelis marmorata*) is a forest-dweller of arboreal habit in the Eastern Himalayas, Assam and Burma. The Golden Cat (*Profelis temmincki*) has a similar range. The Sabre-toothed Clouded Leopard (*Neofelis nebulosa*) inhabits trees in the ever-green forests of Sikkim, Bhutan, Assam and Burma.

Civets.—The Large Indian Civet (*Viverra zibetha*) is found amongst bushes, thick grass or heavy scrub jungle in Nepal, Sikkim, North Bengal, Assam and Burma. The secretion of its perfume gland is reputed to have valuable medicinal and aphrodisiac properties. The other Civets are the Large Malabar Civet (*Moschothera civettina*) confined to Travancore and Cochin, the Burmese Civet (*Moschothera megaspila*) of South Burma, and the smaller Indian Civet (*Viverricula indica*) with several local races widely distributed in the Indian Empire. They live in holes underground or under rocks and bushes, and climb trees. The truly arboreal typical form of Palm Civet or Toddy Cat (*Paradoxurus hermaphroditus*), so called from its habit of drinking toddy tapped into pots on trees, is known from India south of the Narbada River and from Ceylon. It sometimes enters human dwellings. Other Palm Civets are the Brown Palm Civet (*Paradoxurus jerdoni*) from the hill-ranges of South India, and the Chinese Palm Civet (*Paguma larvata*) from the mountain forests of Kashmir, Punjab, Nepal, Assam, Burma and the Andamans, said to live in tree-holes. The Binturong or Bear Cat (*Arctictis binturong*) with a long prehensile tail used in climbing has much the same range as the preceding species and leads an arboreal life in dense forests. The Spotted Tiger Civet (*Prionodon pardicolor*) and the White-

eared Palm Civet (*Arctogalidia leucotis*) are also arboreal forms living in Assam, Sikkim, and Burma.

Mungooses.—There are several species of Mungoose living in forests, cultivated tracts, plantations, swamps, and the banks of rivers and streams. The common Indian Mungoose (*Herpestes edwardsi*) with various colour races and kept by itinerant snake-charmers and mountebanks is widely distributed in India. It lives in forests, in cultivated areas, taking shelter under rocks and boulders, in holes underground, in deserted Termite-mounds, and in human dwellings. The smaller Indian Mungoose (*Herpestes auropunctatus*) living in underground burrows is restricted to Northern India. The Ruddy Mungoose (*Herpestes smithii*) is restricted to forest areas in Central and Western India and Ceylon. The large Stripe-necked Mungoose (*Herpestes vitticollis*) is common in the hills of S.W. India and Ceylon and in the swamps and rice-fields of the Wynaad. The equally large Crab-eating Mungoose (*Herpestes urva*) lives on the banks of rivers and streams at low elevations in the S.E. Himalayas and in Assam and Burma.

Hyaena.—The Striped Hyaena (*Hyaena hyaena*) is an inhabitant of the drier parts of peninsular India among rocky hills and jungles. It does not occur in Ceylon or Burma.

The Dog-group.—The Dog-group consists of two species of wolves, one of jackal, two of wild dogs and five of foxes. A race of the European *Canis lupus* is found in the Punjab and Sind, while the smaller Indian Wolf, *Canis pallipes*, occurs throughout the Indian peninsula. Neither wolves nor foxes are known from Ceylon and Burma. The Indian Jackal (*Canis indicus*) is one of the commonest animals in India at dusk in the vicinity of towns and villages with its familiar long wailing howl and short yelps. Some, at any rate, of the domestic dogs are derived from the wolves and jackals, and the jackals are known to breed freely with dogs. The wild dogs (*Cuon*) are forest animals occurring in the well-wooded parts of India and Burma. The commonest Indian Fox, *Vulpes bengalensis*, which lives in all open parts of the country, ranges from the Himalayas to Cape Comorin and from Sind to Assam.

The Bear-group: Martens, Weasels and Otters.—The Indian Marten (*Martes flavigula*) is an inhabitant of the forests of the Himalayas and of the high hills of Burma. A dark form of this species occurs in the hills of South India. Weasels (*Mustela subhemachalana*) have a similar range. Amongst Badgers the best known is the Indian Ratel (*Mellivora indica*) found on river banks and in the hilly districts of peninsular India, but does not occur in Malabar, Ceylon and Lower Bengal. Of the Otters, the commonest is *Lutra lutra* living in rivers, tanks, and backwaters of India. The smaller Clawless Otter (*Aonyx*) inhabits the Himalayas and the eastern parts of the Empire, and the higher ranges of hills

in S. India. Others are tamed by the fishermen of the Sunderbans and Sind to drive fish into their nets.

Bears.—The Cat-bear or Himalayan Racoon (*Ailurus fulgens*) is met with in the forests of Nepal, Sikkim and the Eastern Himalayas. The Kashmir Brown or Isabelline Bear (*Ursus isabellinus*) occurs in the higher W. Himalayas above the tree-line. The Indian Sloth Bear (*Melursus ursinus*) inhabits bush and forest jungle, and hills, caves, and ravines of the Indian peninsula from the foot-hills of the Himalayas to Cape Comorin and Ceylon.

Insectivora

The Shrews are well represented in India, Burma and the Bay islands. The Tree-shrew (*Tupaia belangeri*) occurs in the tree-forests of Burma, Assam, and the lower Himalayas. True Hedgehogs (*Paræchinus micropus* and *Hemiechinus collaris*) occur in the sandy plains of North-West India. Of the Moles, *Talpa micrura* is common in the forests of Nepal, Sikkim, Assam and Burma. The best known of Indian shrews is the Grey Musk Rat (*Crocidura cærulea*) closely associated with human habitations. Among the water shrews living on the banks of streams of the Himalayan, Sikkim and Burmese forests are *Chimarrogale himalayica* and *Nectogale sikkimensis*. The Flying Lemur (*Galeopterus peninsulæ*) occurs within Indian limits only in the forests of S. Tenasserim, Burma.

Chiroptera

Bats.—Of the Chiroptera or Bats, no less than 32 genera and 80 species have been recognized. We have space to mention only the most common and widely distributed forms in India such as the Indian Fruit-bat or Flying Fox (*Pteropus giganteus*) hanging in hundreds from branches of large trees, the insectivorous bats with nose-leaves such as *Rhinolophus affinis* of the hill-tracts of India, Burma and Ceylon, the Indian Vampire Bat (*Megaderma spasma*) living in caves and old buildings and feeding on other bats, frogs, and insects, the common Yellow Bat (*Scotophilus kuhli*) living in temples, sheds and old dilapidated buildings all over India, and the Painted Bat (*Kerivoula picta*) often found on plantain trees.

Rodentia

There are no less than 40 genera and 136 species of Rodents comprising squirrels, marmots, jerboas, rats and mice, porcupines and hares in the Indian Region. It is impossible to mention in this Outline more than a few of the commonest species occurring in it.

Squirrels.—The Flying-squirrel (*Petaurista oral*) lives in holes of trees. Of the ordinary Squirrels, *Ratufa indica* inhabits high trees in forests throughout peninsular India, and the common Striped Squirrel (*Funambulus palmarum*) lives in the more open cultivated parts, and in or near human habitations. The closely allied Marmots are inhabitants of the bleak regions of the higher Himalayas, and *Marmota himalayana* is the best known example.

Jerboas.—Within Indian limits the Jerboa (*Alactagulus indicus*) is known only from the plains south of Quetta at an elevation of

6,000 feet above the sea-level and from the N.W. Frontier where it lives in burrows. The Malabar Spiny Mouse (*Platacanthomys lasiurus*) lives in hollows of trees in Coorg, Anamalais, and the Malabar and Travancore hills.

Rats, Mice and Bandicoots.—The only Indian Gerbille is *Gerbillus gleadowi* from Sind and Thar deserts. Of the stout Bandicoots which are associated with human habitations and cultivated tracts and cause considerable damage to crops, etc., the best known are *Bandicota eliotana* and *B. malabarica*, the North and South Indian representatives respectively of the genus.

The Coarse-haired Bush-rat (*Golunda ellioti*) is also reputed to be destructive to coffee and other plantations in peninsular India. The common Indian Rat (*Rattus rattus*) is the widely distributed, probably indigenous, representative of the genus, while *R. decumanus* is the imported European Black Rat common in Indian ports. The genus *Mus* includes species of House-mice which are Palæarctic in distribution but have been helped by the human agencies of trade and commerce to spread themselves in the Oriental Region. The Long-tailed Tree-mouse (*Vandeleuria oleracea*) inhabits trees and shrubs and even houses in nearly all parts of Northern India.

Porcupines.—The best known Indian Porcupine (*Acanthion leucura*) lives in caves amongst rocks, in burrows on rocky hill-sides or river-banks all over India and Ceylon, while the Brush-tailed Porcupine (*Atherurus macrourus*) lives in the forests of Lower Burma.

Hares.—The Long-eared common North Indian Hare (*Lepus ruficaudatus*), and the black South Indian, *Lepus nigricollis*, live in waste lands amongst grass and bushes. The Mouse-hares (*Lagomys*) haunt rocky situations or pine forests of the higher ranges of the Himalayas.

Ungulata

The Ungulates constitute a very important group of animals in Indian economic life. The hoofed forms include the Elephant, Rhinoceros, Tapir, Horse, Cattle, Deer and the Pig which fall within four well-defined groups. They are ground dwellers, and barring a few, the majority of them are slender-limbed and fleet-footed in keeping with their habitat in open tracts where their enemies in pursuit are outdistanced by their speed of progression.

Even-toed Ungulates.—The Pecora or typical ruminants in India consist of wild and domestic cattle, sheep and goats, antelopes, gazelle and deer. Of these, all but the last are hollow-horned.

Cattle.—The Gaur or Indian Bison (*Bibos gaurus*) is essentially an inhabitant of the mountains and the larger hill-forests of India and Burma, while the Gyal (*Bibos frontalis*), a cross-breed between the bull Gaur and the domestic cattle, is found in the mountainous tracts of Assam and Burma (Plate V). The Banting or the Wild Ox

of Burma (*Bibos banteng birmanicus*) prefers the undulating or flat country or the lighter forests of Burma to hills. The Yak (*Pœphagus grunnieus*) does not strictly belong to the Indian fauna, being found only in the desolate mountains of the Tibetan plateau. The Indian Wild Buffalo (*Bubalis bubalis*) inhabits mainly the plains of the Ganges and Brahmaputra, the grass jungles of the Terai and Orissa and the eastern parts of Central Province.

Sheep and Goats.—The Wild Sheep or Oorial (*Ovis vignei*) has a varied habitat, from open valleys, hill-sides and grassy slopes in Ladak to rocky scrub-covered or barren hills of the Punjab, Sind, and Baluchistan. The great Tibetan Sheep (*Ovis ammon hodgsoni*), an inhabitant of the Himalayas, occasionally strays into Nepal, Kumaon, and Sikkim, while the Marcopolo's Sheep (*Ovis ammon poli*) lives in Hunza, Kashmir. The smooth, Round-horned Bharal (*Pseudovis nahoor*) lives in the rich grass lands between tree- and snow-line of the Himalayan ranges in Ladak, Nepal and Sikkim. The Sind Wild Goat (*Capra hircus blythi*) with its long scimitar-like horns lives in the barren hills of Baluchistan and W. Sind which are covered with stones and cactus, while the Markhor (*Capra falconeri*) with its spiral horns inhabits the most broken and precipitous country of the Suleman range and the mountains of Kashmir. The Asiatic Ibex (*Capra sibirica*) lives in the W. Himalayas above the tree-line. The Tahr, wild goat of the genus *Hemitragus*, inhabits the rocky forests of the southern slopes of the Himalayas and the open cliffs and precipitous slopes of the Western Ghats and Nilgiris living on grass growing between rocks or on adjacent grass downs. The Serow, Goral or Takin, also called the Goat-antelopes (Rupicaprinæ) because of the intermediate position they occupy between the goats and the antelopes, live in the thickly wooded parts of the Himalayas and in Burmese hills.

Antelopes.—The Antelopes (Antilopinæ) are ruminating Ungulates representing a transition between the oxen and the goats, and the only representative of this group in India is the Black Buck or Indian Antelope (*Antilope cervicapra*) with its beautiful spirally twisted horns which lives in scrub-covered or cultivated plains all over India except the Malabar coast. The Chinkara or Indian Gazelle (*Gazella bennetti*) is also an inhabitant of thin jungle or desert of the plains. The Nilgai or Blue Bull (*Boselaphus tragocamelus*) living in the open jungles or the hilly regions south of the Himalayas (except East Bengal, Assam and Malabar coast), and the four-horned Chousingha (*Tetraceros quadricornis*) with its peculiar glands on the hind false hoofs inhabiting the foot-hills of the Himalayas and the hill-tracts of peninsular India are representatives of Tragelaphine antelopes.

Deer.—The Deer are represented by several species. The Musk Deer (*Moschus moschiferous*) is a form intermediate between the antelopes and the deer, without horns but with strongly

developed canine teeth, gall-bladder, and a musk gland beneath the skin of the abdomen in the male, and lives above the pine zone of Kashmir, Nepal and Sikkim. The Muntjac, Rib-faced or Barking-deer (*Muntiacus muntijak*) is found all over India and Burma in more or less thick jungles. The Chital or spotted deer (*Axis axis*) is confined to India and Ceylon inhabiting the forests of Himalayan foot-hills and the more or less open jungles of Terai, Central Province and South India. The Hog-deer (*Hyelaphus porcinus*) lives in grass jungles of deltas, river-banks, and plains of N. India, in the scrub-jungle of Sind, and amongst the mangrove formations in Burma. The Indian Sambar Deer (*Rusa unicolor*) has a wide range in the Indian Empire and lives in forested hilly tracts not far from cultivation. The Swamp Deer or Barasingh (*Rucervus duvaucelli*) lives in marshes of the Terai and the Sunderbans and in the grassy plains of Central and United Provinces and of Assam. The Indian Chevrotain or Mouse-deer (*Moschiola meminna*) is a true ruminant without antlers, and, as its name indicates, is of very small size usually under 12 inches in height; it lives in grass-covered rocky hill-sides or in forests of Central and Southern India. There are two Burmese species, *Tragula canescens* and *T. kanchil*.

Boars and Pigs.—The Indian Wild Boar (*Sus cristatus*) is widely distributed in the Indian Empire and lives in grassy jungle tracts or in forests. The smaller Andaman Pig (*Sus andamanicus*) is peculiar to the forests of Andaman Islands, where it is seen in groups on the coastal fringe of the islands. The Pigmy Hog (*Porcula salvania*), only 12 inches high, is known only from the forests of the Himalayan foot-hills in Nepal, Sikkim, Bhutan and Assam.

Odd-toed Ungulates.—The Odd-toed Ungulates (Perissodactyla) are represented by the Horse, Rhinoceros, and Tapir. The horse family has within Indian limits only two species, the Kiang (*Equus kiang*) which lives in the open table-lands of Ladak, and Ghor-Khar or Indian Wild Ass (*Equus onager indicus*) which inhabits the plains and desert zones of Cutch and the areas west of the Indus.

Rhinoceroses.—The great Indian One-horned Rhinoceros (*Rhinoceros unicornis*), once widely distributed along the base of the Himalayas from Peshawar to Assam is at the present day confined to the part of Nepal east of the Gandak river and to Assam. It lives in swamps and grass-land and in the jungles of low hills. The smaller one-horned Javan Rhinoceros (*R. sondaicus*), an inhabitant of tree-forest up to an elevation of 7,000 feet, once abundant in Bengal, Assam and Burma, is probably at present confined to Malaya and Java. The Two-horned Rhinoceros (*R. sumatrensis*) was in former times common in the hill-forests of Assam and Burma, but is at the present time confined to certain districts of Burma.

Tapirs and Elephants.—The Tapir [*Tapirus* (*Acrocodia*)

indicus] is rare within Indian limits and occurs in the dense forests of South Tenasserim in Burma. The Indian Elephant (*Elephas maximus*) frequents hilly or undulating country covered with tall forests and thickets of bamboo all over the Indian Region, particularly in Mysore and Burma. It does not, as a rule, breed in captivity, but a few instances of such breeding are known in Burma and in the Andamans.

Edentata

The Scaly Ant-eaters are represented in the Indian Empire by three species, *e.g.*, *Manis crassicaudata*, the Indian Pangolin, from the foot-hills of the Himalayas to Cape Comorin, *M. aurita*, the Chinese Pangolin from E. Himalayas, Assam and Burma, and *M. javanica*, the Malay Pangolin, from Bengal and Burma. All of them live in burrows dug by themselves or amongst rocks.

Cetacea

Of the truly aquatic mammals living within Indian limits there are very few species. The Gangetic Dolphin (*Platanista gangetica*) lives in the muddy waters of the rivers, Ganges, Brahmaputra and Indus, and of their tributaries and tidal creeks, but is not known to enter the sea. It has rudimentary eyes and is quite blind. The large Right Whale (*Balœnoptera indica*) is sometimes reported as having been seen in the Bay of Bengal and Arabian sea by sailors. Several animals have, however, been stranded on the coasts of Burma, Ceylon, Malabar, Sind and Baluchistan. The Sperm-Whale or Cachelot (*Physeter macrocephalus*) is found generally in large herds in the open sea in the Bay of Bengal and round Ceylon. An individual of this species was stranded at Madras in 1890. The smaller Sperm-Whale (*Cogia breviceps*) is also reported to live in the Indian seas, and a young specimen was captured at Vizagapatam on the east coast. The Indian Pilot Whale (*Globicephalus indicus*) has been observed only once in brackish water of the Salt Lakes, Calcutta, in 1852. Of the porpoises, the Indian form (*Phocœna phocœnoides*) occurs generally in tidal rivers such as the Hughli at Calcutta, and in shallow waters along the Indian coasts and the Bay Islands, while *Orcella brevirostris* occurs in the Bay of Bengal. *Orcella fluminalis* is found only in the Irrawady River, Burma. The Dolphins of the genera *Lagenorhynchus*, *Steno* and *Delphinus* have only occasionally been found along the coasts of India, Burma, Ceylon, and the Andaman and Nicobar islands.

Sirenia

The Dugongs, once fairly common, have become very rare along the Indian coasts. *Halicore dugong*, the Indian Sea-cow, has been observed on the coasts of Malabar, Gulf of Manaar, Andaman Islands and the Mergui Archipelago.

Aves.

The Birds of the Indian countryside, jungles and hill-tracts are of considerable interest from the point of view of their

variety and distribution. No less than 2,300 species and subspecies of Birds have been recognized. They belong to the many different habitats dealt with in connection with Mammals, Reptiles and Batrachia. Some species are resident in the Indian Region while others are visitors from the colder northern latitudes. The latter are therefore found in India during the winter months. Some of the most notable among the winter visitors are the Jackdaws, Rooks, Starlings, Martins, Cranes, Gulls, Pelicans, Swans, Terns, Curlews, etc. Some families of Birds include both resident and migratory species. Within the space available for the present Outline of the Indian fauna it is impossible to mention more than a few families of Birds which are of common occurrence in the Indian Region. The Passerine or Perching Birds constitute a vast assemblage of very closely interrelated species forming nearly a third of the total number of known species and subspecies.

Passeres.

Crows, Thrushes and Bulbuls, etc.—The Ravens, Crows, Rooks and Jackdaws are included in the Crow-family. The Jungle-crow (*Corvus coronoides*) and the ubiquitous House-crow (*C. splendens*) have a wide range from the Himalayas to Cape Comorin and Ceylon. The latter species is closely associated with human habitations in village, town or city. The Jackdaw and Rook are winter-visitors to N.W. India. The Indian Magpies (*Cissa*) are birds of beautiful plumage and red bills found in forests. In the plains the Tree-magpies (*Dendrocitta* and *Crypsirhina*) are common. The Titmouses (Paridæ) which are closely allied to the crows are found all over the Indian Empire. The Indian Parrot Bills and Suthoras (Paradaxornithidæ) are gregarious birds of the higher altitudes in E. Himalayas, Assam and Burma. The Nut-hatches (Sittidæ) are small slatey-blue birds which climb up stems of trees and surfaces of rocks and are mostly confined to the hills. The Thrushes and Babblers (Timaliidæ) are gregarious ground-feeders, the majority of which are Himalayan, Assamese and Burmese, but one species (*Pyctorhis sinensis*) has a wide distribution in India and Burma. The Bulbuls (Pycnonotidæ) are common all over India in gardens, cities and towns, but some are forest dwellers in the Himalayan and Burmese regions. Those with bright yellow or crimson tail coverts (*Pycnonotus*, *Otocampsa* and *Molpastes*) are some of the commonest Bulbuls of the plains. The Dippers (Cinclidæ) with special adaptation for a more or less aquatic life inhabit the rapid streams of high altitudes. The Shortwings, Chats, Forktails, Robins, true Thrushes with squamated plumage in the young inhabit the high hills, or the open, barren and cultivated tracts of India, Burma and Ceylon.

Fly-catchers, Drongos, etc.—The Fly-catchers (Muscicapidæ) are both resident and migratory birds. The beautiful Indian Paradise Fly Catcher (*Tersiphone paradisi*) frequents gardens, light forests, open country near villages and feeds entirely on the wing.

The Shrikes (Laniidæ), the Minivets (Pericrocotidæ), and the Drongos (Dicruridæ) are all closely allied families. The last-named (also called King-crows) are among the most common of Indian birds with glossy plumage and long forked tail and with musical voices. Like the Fly-catchers they also catch insects in the air. The Warblers (Sylviidæ) are small plain-plumaged birds of migratory or resident habit. They include the Tailor-birds (*Orthotomus*) well-known for their habit of sewing two leaves together with a piece of grass as a receptacle for their nest. The Yellow or Black Orioles (Oriolidæ) live in the plains as well as on the hills, the best known and widely distributed species being the Indian Golden Oriole (*Oriolus oriolus kundoo*). The Mainas of the families Eulabetidæ and Sturnidæ are also common throughout the Indian Region. The Indian Grackle (*Eulabes javana intermedia*) and the common Maina (*Acridotheres tristis tristis*) are familiar birds. The former is a favourite cage-bird in Assam and Burma because of its long life and extraordinary powers of mimicry of human voice. The latter is also used as a pet. The Weaver-birds (Ploceidæ) are also common in the Indian Region. Their curious flask- or retort-shaped grass nests on the leaves of date-palms, or on the branches of *Acacia* and other trees, or on bushes are a common enough feature of the country side. The Finches (Fringillidæ) are mostly migratory birds, but the Indian House-sparrow (*Passer domesticus*) with its three distinct races is the commonest species throughout the Indian Empire.

Swallows and Larks, etc.—The Martins and the true Swallows (Hirundinidæ) are both resident and migratory birds. Some of them are Himalayan while others are widely distributed. The migratory species when they visit India in winter from the northern latitudes spread gradually over the Indian peninsula and Ceylon. The Wagtails and Pipits (Motacillidæ) and the Larks (Alaudidæ) are widely distributed within Indian limits. The Bush and the Sky Larks are the best known, and the Desert Lark is found only in the Indus plain. The Indian Ruby Cheek (Chalcopariidæ) of low altitudes in the Terai, Sikkim, Assam and Bengal builds curious pear-shaped dome-like nests with the black fibres of certain ferns. The Sunbirds (Nectarinidæ) are of small size with a slender bill and a bright metallic-tinted plumage in the male. Some are widely distributed while others are restricted to hill-forests. The Flower-Peckers (Dicæidæ) are small forest birds frequenting the tops of high trees and found throughout the Indian region. The small beautifully coloured, broad- and flat-billed birds of Burma (Broadbills—Eurylaimidæ) live in small flocks among high trees.

Coraciiformes.

There are several species of non-migratory Wood-Peckers (Picidæ) living on the hills or in well-wooded country, but the two commonest species are the golden-backed *Brachypternus benghalensis* and the yellow-fronted pied *Leiopicus mahrattensis*. The Barbets (Capitonidæ) are well-

represented in India. Most of the species are grass-green in colour and frugivorous in habit. The best known Indian Barbet is the copper-smith bird, *Xantholæma hæmacephala*, whose distinctive metallic monotonous call may be heard in most Indian gardens.

Cuckoos and Parrots, etc.—To the Cuckoo family (Cuculidæ) belong the Indian Brain-fever Bird (*Heirococyx varius*) with its monotonous call-note in the hot season, the well-known mimic (*Surviculus*) of the common Black Drongo-shrike or 'King-Crow', and the Indian Koel (*Eudynamis scolopaceus*). The last named is widely distributed in India and Ceylon except in the very dry regions and is parasitic on the Corvidæ laying its eggs in the crow's nest. The Parrots or Paroquets (Psittacidæ) with long tails and green plumage are another common feature of the Indian Region. *Psittacula krameri*, the Rose-ringed Paroquet, is the commonest of Indian species inhabiting all open well-wooded country in the vicinity of human habitations. The Rollers or Blue Jays (Coraciidæ) are common throughout India in gardens, villages and on telegraph wires alongside railways. The King-fishers (Alcedinidæ) with black and white, green and blue, or violet and chestnut plumage are another common feature of Indian bird-life. The best known species are *Ceryle rudis* (Red King-fisher), *Alcedo atthis* (Common King-fisher), *Halcyon smyrnensis* (White-breasted King-fisher), and *Entomothera coromanda* (Ruddy King-fisher).

Hornbills, Hoopoes and Swifts.—The Hornbills (Bucerotidæ) are typical Indian birds. The female during incubation remains enclosed in a built-in hollow of a tree and is fed by the male. The smaller species, like *Lophoceros birostris* (common Grey Hornbill), prefer the open country to forests, while the larger species like *Dichoceros bicornis* (the Great Hornbill), *Hydrocissa malabarica* (the Pied Hornbill) and *Aceros nepalensis* (the Rufous-necked Hornbill) inhabit ever-green or deciduous forests. The Hoopoes are both migratory and resident birds, the Indian *Upupa epops orientalis* being found throughout India. The common Swifts, and those which make the well-known edible nests (*Micropus affinis*), the Palm Swift (*Tachornis batasiensis*), and the Edible Nest Swiftlet (*Collocalia unicolor*) are among the best known Indian species.

Owls.—The Owls, the Nightjars or Goat Suckers, and the Frog-mouths form a group of closely allied and widely distributed families. 35 species of owls are known from the Indian Region. The Indian Barn Owl (*Tyto alba javanica*), the Brown Fish Owl (*Ketupa zeylonensis*), the Great-horned Owl (*Bubo bubo bengalensis*), the various forms of Scops Owls (*Otus bakkamœna*), and the Spotted Owl (*Athene brama brama*) are among the best known forms.

Accipitres

Diurnal Birds of Prey.—The Diurnal Birds of Prey form a compact group of 3 families containing the Ospreys, Vultures, Falcons, Hawks, Kites, Eagles and Buzzards including no less than 74 species. On the sea-coasts

or on large inland waters of India the Osprey (*Pandion haliætus*) is a winter visitor. Of the Vultures, the long-billed *Gyps indicus* and the white-backed *Pseudogyps bengalensis* occur practically throughout India and Burma. The Falcons include species with wide or restricted distribution some of which are of migratory habits. The best known of Indian Falcons and Eagles are *Falco peregrinus peregrinator* and *Aquila rapax vindhiana*. The Hawk-eagles are inhabitants of forests, while the Crested Serpent-eagle (*Spilornis cheela cheela*) is a soaring bird of the forests and plains. The white-bellied Sea-eagle(*Haliæetus leucogaster*) is common on the coasts of India, Ceylon and Burma and ascends tidal rivers to great distances inland. Amongst the widely distributed and well-known kites are the Brahminy kite (*Haliastur indus indus*) and the common Pariah kite (*Milvus migrans govinda*). The Indian Shikra (*Astur badius dussumieri*), one of the true Hawks, occurs throughout India in groves and orchards and is tamed for hunting Quails and other small game birds and even Crows and Herons. The Indian Crested Honey-buzzard (*Pernis ptilorhynchus ruficollis*) is not uncommon in the plains of India. It feeds on bees and their products, small frogs, reptiles, birds and mammals.

Columbæ and Pterocletes

Pigeons, Doves and Sand-grouse.—The Pigeons and Doves are common in all parts of the Indian Empire. The Green pigeons (Treroninæ) live in flocks in forests, and among trees in towns and villages. The large-sized Imperial Pigeons (Duculinæ) of dark-green coppery brown or grey plumage keep to the forest tracts of India, Burma and the Andamans. The Nicobar Pigeon (*Calœnas nicobarica nicobarica*) with long metallic hackles on the neck is an inhabitant of the Bay islands and is a ground-feeder. The true Pigeons (Columbinæ), some of which are winter visitors, include the Indian Blue Rock-pigeon (*Columba livia intermedia*), the Wood-pigeons (*C. palumbus*) and the Stock-pigeons (*C. œnas*). Some of the Doves are resident and others are migratory. The best known species with a wide distribution are the Rufous Turtle-dove, the Spotted-dove, and the Ring-dove of the genus *Streptopelia*. The Indian Emerald-dove (*Chalcophaps indica indica*) is a forest bird living on grains, fruit and termites. It is known to haunt salt-licks in Assam. The Sand-grouse which occupies an intermediate position between Pigeons and true Game-birds is found chiefly in open desert or dry broken country feeding on the ground and drinking water at definite hours of the morning or evening. The common Indian Sand-grouse (*Pterocles exustus erlangeri*) and the Painted Sand-grouse (*P. indicus*) are among the best known forms.

Gallinæ

Land Game-birds.—The true land Game-birds (Gallinæ) include the Pea- and Jungle-fowls, the Pheasants, Partridges, Quails and the Megapodes and are represented by 64 species. Pea-fowls are met with throughout India in a wild and domesticated state. The best known Pea-fowl

is *Pavo cristatus.* The Argus Pheasants (*Argusianus argus*) are confined to Tenasserim in S. Burma, while the Peacock Pheasants (*Polyplectron bicalcaratum*) are common in the forests of the Lower Himalayas, Assam and Burma. Of the true Jungle-fowls, the common Red Jungle-fowl (*Gallus bankiva murghi*), from which all domestic fowls are derived, is distributed as far south as Godavari River, while the Grey Jungle-fowl (*G. sonneratii*) is found in Central and South India, and *G. lafayettii* in Ceylon. In the Eastern Himalayas, Assam and Burma occurs a large variety of Pheasants, Quails, Koklas, Monals, and Partridges some of which have a wide range of distribution. The Megapodes (*Megapodius nicobariensis nicobariensis*) are inhabitants of the Nicobar Islands, and are remarkable for the fact that the young are born fully feathered and the eggs are deposited in huge mounds of sand and vegetable matter in the dense forests along the shores of these islands. The heat generated by the fermenting vegetable matter is sufficient to incubate the eggs.

Grallæ

Aquatic Game-birds.—The Rails, Crakes, Moorhens, and Coots (members of the family Rallidæ) live hidden amongst reeds, or in grassy swamps, weedy lakes, and small streams, and are consequently seldom seen. The White-breasted Water-hen (*Amaurornis phœnicurus phœnicurus*) and the Moor-hen (*Gallinula chloropus indicus*) are widely distributed throughout India and Burma. The Water-cocks or Kora (*Gallicrex cinerea*) are tamed as fighting birds by the people of Sylhet who hatch the eggs by tying them against their waists. The Masked Fin-foot (*Heliopais personata*) inhabits the swamps of the flooded forests of Assam and Burma. Other common birds of the swamps and lakes (in the plains and in the lower Himalayas up to 5,000 feet) with plenty of reeds, lilies and lotuses are the Bronze-winged Jacana (*Metopidius indicus*), and the Painted Snipe (*Rostratula benghalensis benghalensis*).

Cranes, Bustards and Floricans.—The true Cranes (Gruidae) are represented in India by six species of which the Demoiselle (*Anthropoides virgo*), the common Crane (*Grus grus lilfordi*), and the Siberian Crane (*Grus leucogeranus*) are winter visitors to Northern India. The Sarus Crane (*Antigone antigone antigone*) is a resident bird of the well-watered open plains.

Of the Bustards (Otididæ), the Great Indian Bustard (*Choriotis nigriceps*) haunts the plains of N.W. India and Deccan, while the Floricans (*Sypheotides indica* and *Houbaropsis bengalensis*) are met with in Peninsular India and in the plains of the Ganges and Brahmaputra respectively.

Charadriiformes

Plovers.—The Stone Plovers, Sand Plovers, Crab Plovers form a small group of birds of more or less similar habits. The Indian Stone Plover (*Burhinus œdicnemus indicus*) frequents arid country and sandy beds of rivers all over the Indian Empire. Some Stone Plovers (*Esacus,*

(*Orthorhamphus*) haunt the sandy coasts along the Bay of Bengal, Ceylon and the Andaman islands. The Indian Courser (*Cursorius coromandelicus*) is an inhabitant of the more open and desert portions of India, scrub or grassy country, cultivated or waste land, while the Jerdon's Plover (*Rhinoptilus bitorquatus*) has a restricted distribution in the forest regions between the Godavari River and Madras. The Sand Plover (*Glareola lactea*) frequents stretches of shingle and sand of the larger rivers of India, while the Crab Plover (*Dromas ardeola*) is locally distributed in the Bay Islands and Mergui Archipelago.

The Charadriid Plovers, and the Curlews, Woodcocks, Snipes and Sand-Pipers (Scolopacidæ) include a large number of forms which are migratory and straggle down in winter as far south as Ceylon. The Great Sand-Piper (*Tringa ochrophus*) is known as the Snippet in India. Among the common snipes of India are the Fantail (*Capella gallinago*) the Pintail (*C. stenura*), the Wood-snipe (*C. nemoricola*) and the Eastern Solitary Snipe (*C. solitaria*). The last two are resident in the lower Himalayas, Assam and Burma. *C. nemoricola* extends to the hills of South India during winter.

Gulls and other Water-birds.—There are large numbers of Water-birds such as Gulls, Terns, and Skimmers many of which are winter-visitors to India straggling far inland to large areas of water such as rivers and lakes. Amongst the commonest of these are the Black-headed or Laughing Gull (*Larus ridibundus*, and the Yellow-Legged Herring Gull (*L. argentatus*), the Indian River Tern (*Sterna aurantia*) which keeps to the larger Indian rivers, the Black-bellied Tern (*S. melanogaster*) which frequents large lakes, swamps and rice-fields, and the Indian Skimmer (*Rhyncops albicollis*) living on the surface organisms such as small Crustacea, Fish, etc., in the larger rivers of India and Burma.

Steganopodes and Turbinares

Pelicans.—Amongst the Pelicans (Pelecanidæ), the eastern White or Rosy Pelican (*Pelecanus onocrocotalus roseus*) wintering in Northern India, and the Spotted-billed Pelican (*Pelecanus philippensis*) breeding in winter in South India, Ceylon and Burma, are common.

Cormorants and Snake-birds are inhabitants of freshwater areas all over the Indian Empire, but the former may often be seen fishing in the mangrove swamps and the sea. The Little Cormorant (*Phalacrocorax niger*) breeds in lakes and swamps during the monsoon. The Snake-bird (*Anhinga melanogaster*) is entirely a freshwater bird throughout the Indian Region.

Oceanic Birds.—The Gannets or Boobies (Sulidæ), black or brown birds of large size, inhabiting the open sea are casual visitors to the shores of India. The closely allied Tropic or Bosun Birds (Phæthonidæ) are oceanic birds following ships for many miles out at sea and visiting the coasts only for breeding purposes. The Frigate Birds (Fregatidæ) and the Petrels (Procellariidæ) are also

oceanic species recorded from the islands of the Indian Ocean, and from Ceylon.

Herodiones and Phœnicopteri

Storks, Herons, etc.—The Spoonbills, Ibises, Storks, and Herons constitute an important element in the bird life of India. The Spoonbills (Plataleidæ) have a range extending from Sind to Bengal and Ceylon. Within the Indian limits the Ibises (Ibididæ) inhabit rivers, lakes and swamps, and open dry cultivated country, and avoid deserts or the wettest regions of Bengal, Assam and Burma. The Storks (Ciconiidæ) include winter-visitors and resident birds. The common White-necked Stork (*Dissoura episcopa episcopa*) and the curious Open-bill (*Anastomus oscitans*) are among the resident species. The commonest of the Herons and Egrets are the Grey Heron (*Ardea cinerea cinerea*), the Purple Heron (*A. purpurea manillensis*), the White Egret (*Egretta alba*, *E. intermedia* and *E. garzetta*), and the Cattle Egret (*Bubulcus ibis coromandus*). The Reef-Heron (*Demiegretta sacra* and *D. asha*) are coastal or insular birds found on the coasts of Burma, Andamans, Ceylon, Laccadives, Sind and Mekran. The Indian Pond Heron (*Ardeola grayii*) is one of the commonest and best known birds of India, grayish-brown when sitting and white in flight. The Night Heron (*Nycticorax nycticorax*) is a truly nocturnal bird living in the deep shade of trees by day and flying at dusk to the feeding grounds near water. The Bitterns are crepuscular in habits and hide in long grass and reeds. The Chestnut Bittern (*Ixobrychus cinnamomeus*) breeds on the west coast of India and is a common resident of Bengal and Assam. The Flamingo (*Phœnicopterus ruber antiquorum*) is found as far down as Ceylon and east to Assam on the shores of lakes, and sea-coasts, and breeds in the Runn of Cutch.

Anseres and Pygopodes

Swans, Ducks and Teals, etc.—The Swans (Anatidæ) are rare in India. The Mute Swan (*Cygnus olor*) and Whooper (*Cygnus cygnus*) have been recorded on a few occasions in N.W. India.

Among the Ducks which breed in tropical India are the widely distributed Comb-duck or Nukhta (*Sarkidiornis melanotus*) and the Pink-head Duck (*Rhodonessa caryophyllacea*). The Mandarin Duck (*Aix galericulata*) is an extremely rare visitor to Assam. Of the true Geese (Anserinæ) only a few visit N. India and N. Burma during winter, such as the Gray Lag (*Anser anser*) migrating as far south as Bombay and the Chilka Lake and the Bar-headed Goose (*Anser indicus*) which extends down to Deccan and Mysore.

The Teals, Sheldrakes, Mallards, Gray-ducks and Shovellers are mostly migratory. The common Whistling Teals (*Dendrocygna javanica* and *D. fulva*) are permanent residents where swamps and lakes abound. The Brahminy Duck (*Casarca ferruginea*) prefers the larger rivers to lakes and ponds. The Spot-bill (*Anas pæcilorhyncha*) is resident throughout India and Ceylon. The Andaman Teal

(*Nettion albogulare*) is peculiar to the Andaman and Cocos group of islands and inhabits freshwater swamps and tidal creeks. The White-eyed Pochard (*Nyroca rufa rufa*) is one of the commonest of Indian Ducks occurring as far south as Mysore and Madras and is an expert diver. The Smew (*Mergellus albellus*) is a regular visitor to N. India and lives in clear rapid streams. The Eastern Goosander (*Mergus merganser orientalis*) visits the foot-hills of the Eastern Himalayas, and chooses swiftly flowing rivers or torrents, but is equally at home in clear lakes and ponds. The Grebes (Podicepidæ) are expert divers. The Great Crested Grebe (*Podiceps cristatus cristatus*) occurs only in N. India in marshes and lakes and in the sea, while the Indian Little Grebe (*P. ruficollis capensis*) is common all over the Indian Empire.

Reptilia.

In the Indian Empire this group is well-represented by a variety of forms of aquatic, semi-aquatic, terrestrial, and arboreal habits. The curious lizard-like Tuatara, the Alligators, the Iguanas, the Snake-like Amphisbænian Lizards, the Giant Land Tortoises, and the Rattle-snakes and Boas do not occur in this region, although the nearest relatives of all but the first are known from the Empire.

Crocodilia

Crocodiles.—There are only 3 species of Crocodiles in the Indian Region. The Gharial (*Gavialis gangeticus*) the sole living representative of the genus, occurs in the larger rivers of N. India, *e.g.*, the Indus, Ganges, Brahmaputra and Mahanadi living chiefly on fish, birds, and small mammals such as goats and dogs. Occasionally it may attack man. It has the habit of floating at the surface of water with only the eyes and the tip of the snout above water. The estuarine Crocodile (*Crocodilus porosus*) inhabits the coasts of India from Cochin to Ceylon, Bengal and Burma frequenting the deltaic tract of rivers and the backwaters, and enters the sea for several miles from the coasts. It grows to big sizes (over 20 feet long) living on fish, turtles, birds, crabs and even insects, and attacks man. The Mugger or Broad-snouted Marsh Crocodile (*Crocodilus palustris*) lives in freshwater swamps, tanks and rivers throughout the Indian peninsula and Ceylon, and in Baluchistan, Nepal, and in the Brahmaputra river. In the dry season it buries itself in mud to æstivate. It feeds chiefly on fish and birds, but occasionally attacks human beings.

Chelonia

Tortoises and Turtles.—The Tortoises and Turtles are represented by several genera and species. Of the latter, the Leathery Turtle (*Dermochelys coriacea*), the largest of all marine Chelonians, is found only on the coasts of Ceylon and Travancore, while the Green or Edible Turtle (*Chelonia mydas*) is particularly common around the Andaman Islands. The Hawksbill Turtle (*Eretmochelys imbricata*) which provides the

tortoise-shell of commerce is generally distributed in Indian and Indo-Chinese waters, but is not so common as the Green Turtle. The Logger-head Turtle (*Caretta caretta olivacea*) is abundant on the coasts of the Andaman Islands and Ceylon. The freshwater Tortoises (Emydidæ) are represented by no less than 33 species belonging to 15 genera. Several of these are confined to Burma and the Indo-Chinese sub-region. Among these may be mentioned *Geomyda trijuga* with a wide distribution in S. India, Bombay, Bengal, Burma, Ceylon and the Maldive Islands, *Geoclemys hamiltoni* of N. India, *Hardella thurgi* of the rivers Ganges and Brahmaputra, *Kachuga tectum* of the three great rivers of N. India, *Kachuga trivittata* of the Irrawady and Salween river systems, and *Batagur baska* of the estuaries, deep-rivers, and canals of Bengal and Burma. The commonest of the Freshwater and Mud Turtles of the family Trionychidæ are *Lissemys punctata, Chitra indica, Trionyx gangeticus, T. leithi* and *T. hurum*. The land Tortoises (Testudinidæ) are represented by the single genus *Testudo*. *T. elegans* is the commonest South and Central Indian species with the closely allied *T. travancorica* confined to the hills of Travancore. *Testudo emys*, the largest of Asiatic species, lives in the hilly districts of Assam and Burma.

Lacertilia

Gecko Lizards.—The Lizard-group includes a large number (248) of species occurring within the Indian limits, and consists of Geckoes, Chameleons, Skinks, etc. The Geckoes are found everywhere in the plains or at low altitudes except in thick jungle or in water. Some of them are closely associated with human habitations, some are found in deserts hiding under stones and in crevices of rocks, while others live in tree-holes or in cracks under the bark. They feed chiefly on insects. The commonest species are those of the genera *Gymnodactylus* of wide distribution, *Cnemaspis* from the hilly regions of S. India and Ceylon, and *Hemidactylus* with very wide distribution in all parts of the Empire. *Hemidactylus brooki* is the commonest House-gecko in India. The Tuck-too or Tuk-Kaa (*Gekko gecko*) of North-Eastern India and the Andaman Islands are large lizards living chiefly on insects but occasionally attacking larger animals such as other lizards, mice, small birds and even snakes. The parachuted *Ptychozoon kuhlii* of the Nicobars is reputed to fly from one tree trunk to another. The Green Lizard (*Phelsuma andamanense*) with red or orange markings and red tongue is a common inhabitant of the Andaman Islands on trees and in human dwellings. The Fat-tailed Lizard (*Eublepharis macularius*), an inhabitant of desert areas found in N.W. India, lives on other lizards, crickets and other insects, spiders and scorpions.

Ground and Flying Lizards.—The Agamid lizards include species which live on the ground as well as on trees in forests. The Flying Lizard (*Draco*), the so-called 'Blood-sucker' (*Calotes*), the Skinks, the Monitors, and the Chameleons belong to this family.

One species of Flying Lizard (*Draco dussumieri*) is found only in S. India, while the others, *D. maculatus*, *D. tæniopterus*, *D. blanfordi* and *D. norvilli* are not found west of Assam. Another common lizard of the drier and open districts of India and Ceylon is *Sitana ponticeriana*. Several species of *Calotes* are known, but the commonest species on the plains and hills of India and Ceylon is *Calotes versicolor*. The lizards of the genus *Agama* are found chiefly in the rocky country of North-West India, and feed on vegetable matter and insects. They hibernate during the cold season. The lizards of the genus *Uromastix* live in holes in the ground made by themselves in arid tracts. The Spiny-tailed Lizard (*U. hardwickii*) of N.W. India inhabits sandy tracts where vegetation is scanty and feeds on grass, flowers and fruit. It hibernates in its burrows during the cold weather.

Chameleons.—The Chameleons have their home in Madagascar and Africa, but in the wooded districts of peninsular India and in the dry zone of Ceylon they are represented by one species, *Chameleon zeylanicus*. They have the power of independent movement of the eyes, and an extremely extensible cylindrical sticky tongue, and can change their colour at will.

Skinks.—The very numerous species of the skink family (Scincidæ) include forms which live in damp places near rocky streams (the viviparous *Tropidophorus*), forms that live near the sea-shore (*Mabuya bibronis*), and forms that live in burrows and are crepuscular or nocturnal (*Barkudia insularis*) . Of the commoner Skinks are *Mabuya carinata* of peninsular India, *M. beddomii* of S. India, and *M. dissimilis* of N. India. The largest of the Indian Skinks (*M. tytleri*) is peculiar to the Andaman Islands. *Dasia olivacea* of Tenasserim and the Andaman and Nicobar Islands is arboreal in habit. Other common forms are *Lygosoma indicum* of the E. Himalayas, Assam and Burma, *L. dussumieri* of S.W. India, *L. taprobanense* of Ceylon, *Leiolopisma himalayanum* of the sub-Himalayan tract up to elevations of 12,000 feet, and *Riopa punctata* widely distributed in the hilly parts of India and Ceylon. The 'Sand-fish' (*Ophiomorus tridactylus*) which burrows in sand is common in the desert and shady parts of India. Another similar form which burrows in loose earth is *Barkudia insularis* of the Chilka Lake on the east coast of India. The degenerate Ceylon Skinks of the genus *Nessia* live in earth or decaying vegetation or under stones, and feed on worms. The snake-like, externally limbless Burmese Glass-snake (*Ophisaurus gracilis*) is common in the Himalayas, Assam and Burma.

Monitor Lizards.—There are six species of Monitors (*Varanus*) within Indian limits. The Desert Monitor (*Varanus griseus*) inhabits sandy places in N.W. and Central India where vegetation is scanty. *Varanus monitor*, the common Indian Monitor occurs throughout India, Burma and Ceylon while the common Water

Monitor (*V. salvator*) frequents rivers, estuaries and sea-coasts of Bengal, Burma and Ceylon. There is a considerable trade in lizard skins in India.

Ophidia

Snakes.—The Snakes constitute a large and important element in the Reptilian fauna of India, and there is no known family of living snakes which is not represented in this country. The large number of deaths amongst domestic animals and human beings caused by the bite of poisonous species of snakes has focussed much attention on this group. Zoologists and medical men have attempted to provide intelligible guides to the lay people to distinguish at sight poisonous from non-poisonous snakes. Amongst the commonest species met with in the Indian Empire may be mentioned the Carpet-snake (*Lycodon aulicus*), the Rat-snake or Dhaman (*Ptyas mucosus*), the Grass- and the Water-snakes (*Rhabdophis stolatus* and *Nerodia piscator*), the Tree or Whip-snake (*Dryophis mycterizans*), the Cobra (*Naia naia*), the Krait (*Bungarus candidus*) and the deadly Russel's Viper (*Vipera russelli*). The Sea-snakes (Hydrophinæ) with a strong, compressed, oar-shaped tail are also common on the Indian coasts, the most widely distributed being *Hydrus platurus*, and *Enhydrina valakadien*. The latter is known to be the most poisonous of all Indian snakes. There are other snakes not so well-known but which, nevertheless, deserve mention. The burrowing 'Earth-snakes' (Uropeltidæ) are peculiar to the hilly tracts of peninsular India and Ceylon, while the small worm-like sub-terranean snake (*Typhlops*) is widely distributed all over the Indian Empire. Of the latter *Typhlops braminus* is the commonest. The best known Python or Rock-snake of India is *Python molurus*. The so-called Double-headed Snake kept by snake-charmers in this country is *Eryx jaculus* which lives in sandy tracts of Southern and N.W. India. *Cerberus rhynchops* lives in mud on the banks of large rivers and estuaries of the Indian region and feeds on fish. The Raj-samp or Banded Kraits (*Bungarus candidus*) of N. India are common all over the country and destructive to life. The King Cobra (*Naia hannah*) confined to parts of South and Eastern India and Burma, and to the Andamans is of fierce and aggressive habits and feeds on other snakes. *Echis carinata*, another fierce snake of the Viper class, may be met with in the desert or sandy tracts of India. The Pit-Vipers are represented in India by two species only, *e.g. Ancistrodon himalayanus* common in N.W. Himalayas and Assam and *A. hypnale* in Ceylon and the W. Ghats.

BATRACHIA.

Salamanders and Limbless Cœcilians.—The Frogs and Toads, the Newts and Salamanders, and the worm-like limbless Cæcilians which constitute this class have a peculiar distribution in India. The Indian Salamander is represented by a single species (*Tylototriton verrucosus*) which has hitherto been found only in the Eastern

Himalayas and the Shan plateau. The burrowing apodous Batrachians are represented by only five species belonging to 3 genera in the Indian fauna four of which are inhabitants of the Western Ghats of Malabar. The fifth species *Icthyophis glutinosus* occurs in the hills of Ceylon, Malabar, Eastern Himalayas, Assam and Burma in soft mud in damp places.

Frogs and Toads.—The Frogs and Toads are found everywhere in India in damp situations or in ponds, pools, and streams, and are aquatic, terrestrial, arboreal, or burrowing in habit. There are several genera of which *Rana* is the best known. All Indian species of this genus are probably aquatic during the breeding season, but their habits vary greatly. Over 40 species are known of which the most common are the truly aquatic *R. hexadactyla* of S. India and Ceylon, the large *R. tigrina* of all India and Ceylon, and *R. limnocharis* and *R. cyanophlyctis* of wide distribution in the Indian region. The last named live on trees or rocks or in very damp situations in the forests. Among the species of other genera may be mentioned *Micrixalus fuscus*, *Nannobatrachus beddomii* the smallest Batrachian known, *Rhacophorus maculatus* the 'Chunam Frog' of Madras, and *R. reticulatus* the female of which carries the ova in shallow pits in the skin of the ventral surface of the abdomen, and *Ixalus variabilis* of Ceylon, Malabar and the Nilgiris. Of the toothless Engystomatid Batrachians there are several small species represented in the Indian Empire of which the best known are *Microhyla rubra* of S. India and Ceylon, *M. ornata* of a much wider distribution ; the burrowing form *Callula pulchra* with dilated digits, and the toad-like *Cacopus systoma* of peninsular India, Ceylon and Burma. Among the true Toads (Bufonidæ) the best known and the commonest species in the Indian Empire is *Bufo melanostictus*. There are two rare species belonging to families not common in the Indian region which deserve mention. One is *Caluella guttulata* of Burma (Family Dyscophidæ which is common in Madagascar) and the other is *Hyla annectens* (Family Hylidæ of Australia and America) known only from the hills of Assam and Upper Burma. The Burmese (*Leptobrachium carinense* of the rare family Pelobatidæ is known to attack with its strong jaws even small mammals.

PISCES.

The fish fauna of the Indian Empire is of considerable diversity owing to the great variety of habitats met with both in the sea and in the estuarine and freshwater areas. Fish are found everywhere along the coasts of India whether rocky, sandy or muddy, and amongst coral reefs, in deep sluggish rivers or in mountain torrents, in lakes, ponds and wells, in river estuaries, coastal lagoons and backwaters. The distribution of marine fishes is rather wide, and some genera are common to the Indo-Pacific and the Atlantic

regions. It was estimated by Alcock that 57 per cent. of the Indian marine genera were common to the Indian seas and to the Atlantic and Mediterranean. The freshwater fish fauna of the Indian sub-continent has elements in it which are common to the Indo-Malayan and Indo-Chinese regions. Barring the Chiclid *Etroplus* in S. India and Ceylon the African element is absent from most parts of peninsular India. The Lampreys and Hags (Marsipobranchii), the Chimæras or Elephant fishes (Chimæroidei), the Lung-fishes and Mud-sirens (Dipneusta), and the Sturgeons (Actinopteri) are totally absent in India.

Cartilaginous Fishes.—The Cartilaginous fishes such as Sharks, Rays and Skates are well-represented in the Indian seas and estuaries. The coastal waters and the seas in the neighbourhood of the Andaman and Nicobar islands abound in the much-feared large-sized Gray-sharks (*Scoliodon* and *Galeocerdo*), the Hammer-headed Sharks (*Zygæna*) and the Saw-fishes (*Pristis*), the Sting-rays (*Trygon*) with a spiny whip-like tail, the great Eagle-rays or Devil-fish (*Myliobatis*), and the Torpedos and Electric-rays (*Torpedo*, *Narcine*, *Bengalichthys*) some of which give a mild electric shock when handled. The dried fins of Sharks and Rays are exported to China, while some classes of people on the Indian coasts fancy the flesh of these fish. Some of the Sharks and Rays (*Scoliodon* and *Trygon*) ascend the large tidal rivers such as the Ganges.

Bony Fishes.—The bony fishes are, however, the most predominant and best-known fishes of the Indian Region both in the seas and in the fresh- and brackish-water areas. Only a few of the better known families of bony fishes can be mentioned in this Outline. There are several Eels (Symbranchoid, Murænoid) in marine and freshwater areas. Those which inhabit the coral-reefs or rocky shores are brilliantly coloured with bands and spots. The best known genera are *Anguilla* and *Muræna*. The freshwater Spiny-eel (*Mastacembelus*) belongs to another family and is not a true Eel. The scale-less Cat-fishes (Siluroidea) with their well-developed feeler-like barbels are found mostly in muddy rivers and their estuaries and in hill-streams. Some of these (*Wallago attu*, *Bagarius yarellii*) grow to large sizes and are referred to as 'Freshwater Sharks'. There are a few marine genera such as *Arius*. The Carps (Cyprinoidea) are exclusively freshwater in habitat and include important food fishes such as Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mahseer (*Barbus tor*) common in N. India. The Snake-headed Fishes (Ophicephalidæ) and the so-called Climbing-perch (*Anabas testudineus*) are common throughout the Indian Empire in rivers, ponds and marshes and have the power of living out of water for long periods. They are enabled to do so with the help of accessory respiratory organs which develop in various parts of the body (in the head in *Ophicephalus*, in the branchial chamber in *Clarias*, etc.). There are no true Salmon and Trout in India except those that have been introduced in the streams of the hilly parts of

the country. The Indian Herrings (Clupeidæ) include the celebrated migratory 'Hilsa' (*Hilsa ilisha*) of Bengal and 'Pala' of Sind closely allied to the Alice Shad of Europe, the Oil-sardine (*Clupea longiceps*) of the Malabar coast, and the Anchovies (*Engraulis*) are common on the Indian coasts and estuaries. The 'Bombay Duck' (*Harpodon nehereus*), the Gar-pikes (*Belone*) and Half-beaks (*Hemirhamphus*) are also common on the coasts and estuaries. The Flying-fish (*Exocœtus*) is, however, an inhabitant of the open sea. The Indian Perches comprise within it a large number of marine genera and a few freshwater ones (like *Ambassis*, *Nandus*, *Badis*, etc.) many of which include edible forms. The best known of the coastal or estuarine edible fishes are the famous 'Bhekti' (*Lates calcarifer*), 'Topsi' or Mango-fish (*Polynemus paradiseus*), Horse-mackerels (Carangidæ), true Mackerels (*Scomber*), Pomfrets (*Stromateus*), Tunny or Bonito (*Thynnus*), and Grey Mullets (Mugilidæ). Living among the coral reefs and along the rocky coasts are several small Percoid forms of bright colours belonging to the families Plesiopidæ, Glyphidodontidæ, and Labridæ. These are more common in the coastal waters of the Mergui Archipelago and the Andaman and Nicobar groups of islands. The Cod and Haddock (Gadidæ) of Europe are not well-represented in Indian waters, while the Soles and Turbots are represented by several species of Flat-fishes (Heterosomata) which do not have the same reputation as edible fishes as in Europe. The Globe-fishes (Tetradontidæ), the Pipe-fishes (Syngnathidæ) and the Sea-horses (Hippocampidæ) are quite common along the coastal regions and in estuaries, but members of the first two families have been found in freshwater at considerable distances from the sea. The mud-flats and river estuaries and mangrove-swamps have a fish fauna peculiar to such regions. Eel-like Gobioid fishes such as *Tœnioides*, *Pseudapocryptes* and *Apocryptes* burrow in mud where they æstivate in unfavourable seasons. The mud-skippers of the genera *Periophthalmus* and *Boleophthalmus* hop about on land far from the sea and the estuaries. A fish of a similar habit is the Blenniid *Andamia* which lives on rocky shores much above the water-line and sticks to rocks by a special sucker-like mental flap of skin when the surf beats against them.

In structure as well as in distribution the hill-stream fishes are of considerable interest. Several genera are known of which *Pseudecheneis*, *Balitora*, *Psilorhynchus*, *Parasilurus* and others are confined to the Eastern Himalayan region and are not found west of the Teesta valley. In S. Indian hills, *Bhavania*, *Silurus*, and *Parapsilorhynchus* occur and are closely allied to some of the E. Himalayan forms. There are no large inland lakes in India, but those of N. Burma such as the Inlé Lake and the Indawgyi Lake have endemic genera of exceptional interest such as *Chaudhuria* and *Indostomus*. These lakes, and some parts of Assam and the Abor country which are far removed from the sea coast have a peculiar fish fauna including genera common in the seas and estuaries or

their close allies. These genera are *Indostomus*, *Dorichthys*, *Tetraodon*, *Rhynchobdella* and *Moringua*.

ANIMAL COMMUNITIES IN VARIOUS ENVIRONMENTS.

A consideration of the Invertebrate fauna on the same lines as those of the Vertebrate would occupy far more space than is available for this Outline. We shall therefore give a brief account of the various groups of animals which actually occur or may be expected to occur in some of the common types of environments known in the Indian Region.[1]

Cave Fauna.

Caves of any large size or great depth comparable to those of Europe and N. America are not known in the Indian region, but in the limestone districts of Assam and Burma there are a few (Hsing-Daung, Ngot and Moulmein in Burma, and Cherrapunji and Siju in Assam), of which by far the largest known in the Indian Empire is the Siju cave in the Garo Hills of Assam. It is perhaps a matter of common knowledge that most dark places in India abound in Bats. These are the most characteristic animals of caves in general, and provide the bat-guano of high manurial value. The results of a careful investigation of the fauna of the Siju cave revealed a surprisingly small degree of adaptation to cave-life in the hundred and odd species found there. The majority of the species were such as those known to occur in daylight in other situations. Amongst the animals found at distances exceeding 1,500 feet from the entrance of the cave were land animals such as Bats (*Hipposideros*), Rats (*Rattus*) and Wild Cats (pug-marks of *Felis*), Isopods (*Philoscia* and *Cubaris*), Arachnids (*Heteropoda*, *Sijucavernicus*, *Schizomus*), Millipedes and Centipedes (*Trachyiulus*, *Himantostoma*), Insects (Collembola, Orthoptera, Diptera, Lepidoptera and Coleoptera), Earthworms (*Drawida*, *Megascolides*, *Glyphidrilus*); and aquatic animals such as Fish (*Nemachilus*, *Barbus*), Insects (the Gerrid bug, *Metrocoris* and the Gyrinid beetle, *Orechtochilus*) and Decapod Crustacea (*Paratelphusa*, *Palæmon*). The only species amongst these which show definite adaptation to life in caves, such as reduction in the extent of retinal pigment present in the eye or in the size of the cornea, and change in the colour of the body pigment, are *Palæmon cavernicola*, *Philoscia dobakholi* and *Cubaris cavernosus*. The land snail *Opeas cavernicola*, though found not further inside the cave than 500 feet from the entrance, shows modification in the eye. Kemp and Chopra, who investigated the fauna of this cave, are of the opinion that, on account of its comparatively recent origin, the fauna is in an early stage of evolution to the

[1] The following account of the animal communities in various environments has been critically examined by the author's colleagues, Drs. S. L. Hora and B. Chopra, to whom his thanks are due.

highly specialized state so characteristic of the older caves of Europe and America.

Desert Fauna (Plate VI, upper figure).

The little that is known of this fauna indicates that the species constituting it are widely distributed in India and adjacent regions, and are capable of physiological adaptation to the varied conditions of life. Annandale (1906)[1] observed that in the barren coastal plains of a South Indian District (Ramanad) the great majority of species represented have not only a wide distribution but are able to adapt themselves to various environments. Cockroaches (*Blatta* and *Stylopyga*) of this region, for instance, are found elsewhere in very damp situations. Most of the Wasps and Ants have a wide distribution in the Oriental Region. So are all the Butterflies except one (*Catachrysops pandava*). Some of the Arachnids (*Palamnœus* and *Buthus*) have a limited range in S. India. While certain forms such as the Gryllid, *Cophogryllus arenicola*, seem to be adapted to life in barren sand, the great majority of the larger forms are more hardy than specialized so that they are able to endure changing conditions of the environment. The colour of the Arthropods found was generally dull as in most desert localities, but those that were conspicuous had red or black pigment in the integument. Amongst the small Mammals found were the Fox (*Vulpes*), the Hedge-hog (*Erinaceus*), the Squirrel (*Funambulus*), Rats and Mice (*Tatera*, *Rattus*, *Leggada* and *Nesokia*), the Wild-cat (*Felis viverrina* ?) and the Hare (*Lepus nigricollis*). In the Salt Range of the Punjab (Hora 1923,[2] Pruthi, 1933[3]) the general conditions of life are not very favourable for terrestrial and aquatic life. The extremely hot and dry climate which prevails for the greater part of the year, and the high salinity of water in the streams and ponds as a result of the impregnation of the soil with mineral salts are inimical to a rich and abundant animal life. Even so the number of species of animals, terrestrial and aquatic (Reptiles, Batrachians, Fish, Worms, Molluscs, Crustaceans and Insects) which have made this region their home is well over a hundred, the most numerous of these being Insects such as aquatic and terrestrial Beetles, Dipterous Flies, May-flies, Dragon-flies, Caddis-flies, aquatic Bugs, and caterpillars of the aquatic Lepidopteran, *Aulacodes*. A large number of these is widely distributed in N. India or in the Oriental Region as a whole. A few, particularly the Reptiles and Molluscs, belong to the Afghan-Baluch-Persian desert region, and still fewer (Reptiles, Fish and Molluscs) are endemic. The only Palæarctic element in the fauna is a Toad (*Bufo viridis*) which is found outside the Salt Range in

[1] *Mem. As. Soc. Bengal*, I, pp. 183–202, pls. ix-x (1906).
[2] *Rec. Ind. Mus.*, XXV, pp. 369–76 (1923).
[3] *Rec. Ind. Mus.*, XXXV, pp. 87–119 (1933).

the Kashmir valley and in the districts north and west of the Punjab. The devastating invasions of Locusts (*Schistocerca gregaria*) of the years 1926–31 in N.W. India has focussed much attention on the distribution of this typically desert insect in Baluchistan, Sind and Rajputana where solitary forms of this Locust have been found over a wide area.

Hill-stream Fauna (Plate VI, lower figure).

The rapid or torrential streams of the hill-tracts or mountainous regions of India, Burma and Ceylon are inhabited by certain specialized types of animals of groups or families, representatives of which are found commonly in other types of environment such as large rivers, lakes, tanks and estuaries. The inhabitants of the torrential streams are generally members of the groups—Batrachia, Pisces, Mollusca, and Insects, but Leeches, Polyzoa and Turbellarians are also known to live in such environments (Hora, 1927). The environmental conditions in the hill-streams are by no means uniform (Hora, 1930). The slippery moss-grown edge of a boulder or rock over which the stream falls, the spray-covered bare rocks in the vicinity of the falls, the under-surface of submerged rocks and pebbles, the deeper rock-pools in the course of the stream, the marginal area of the stream which may have submerged or overhanging vegetation, all constitute types of environment commonly met with in hill-streams. Where rocks, pebbles, or coarse sand are present one may chance upon Batrachian larvæ (*Hylorana*, *Helophryne*, and *Megophrys*), Fish, such as *Garra*, *Sicyopterus* (of oceanic islands), *Glyptothorax* and *Pseudecheneis* with special adhesive organs which enable them to hold on to rocks, and Loaches (*Nemachilus*) which hide themselves amongst pebbles. Amongst insects which live under stones and pebbles or are attached to rocks are the immature stages of May-flies (Heptageniid Ephemeroptera), Caddis-worms (Trichoptera), Dragon-flies (Gomphid Odonata), Stone-flies (Perlidæ), Coleoptera (*Psephenus* and other Dryopid Beetles) Hemiptera (Naucorid Bugs), the Lepidopteran (*Aulacodes*) with its web-like larval cases, and Diptera (Empidæ, Simulidæ, Blepharoceridæ, and Psychodidæ). The larvæ either cling to rocks by hooks on the limbs and body, or adhere to them by sucker-like devices developed on the ventral surface of the body. Molluscs of the genera, *Paludomus* (Melaniidæ), *Theodoxis* (Neritidæ), *Turbinicola* (Ampullaridæ), and *Ancylus* (Ancylidæ) may also be found sticking firmly to rock-surfaces by means of their broad and muscular foot. In the pools in the course of hill-streams where the flow of water is not very rapid large forms such as the Batrachians, *Rana alticola* and *R. malabarica*, and small Carps (*Danio*, *Rasbora*, etc.), the Notonectid Bug, *Enithares*, Mollusca (*Melanoides*, *Acrostoma*, *Corbicula*) and Crustacea (*Caridina*, *Palæmon* and *Potamon*) may be met with. Living among the

aquatic plants of hill-streams are usually Tadpoles (*Megophrys*), Amphipods (*Gammarus*), Insect-larvæ or nymphs (Tipulidæ, Bætidæ, Simuliidæ, Chironomidæ) and the limpet-like Mollusc, *Ancylus*. Powerful swimmers amongst fish, such as *Barbus* (of the Mahseer type), *Labeo*, *Oreinus*, and *Barilius*, which occur in hill-streams are independent of the conditions governing life under rocks or in still pools of streams. They are of migratory habits and are often seen swimming against the current.

River Fauna.

The river-systems of the Indian Empire are not all of a uniform type, and the fauna of no one of them is completely known. The only river of which the upper reaches have been investigated is the Narbada where the faunistic elements are clearly those of the ordinary hill-stream type. Comparatively little is known of the middle reaches of rivers, but in the Ganges a distinct relict fauna has been observed. Among those included in this fauna are the Cetacean (*Platanista gangetica*), the Amphipod Crustacean (*Ampelisca pusilla*), the Bivalve Molluscs (*Scaphula deltæ* and *S. celox* and *Novaculina gangetica*) which have abandoned their ancient home in the sea and settled down to the conditions of life in the middle reaches of the Ganges. The Vertebrate elements of the rivers of India have already been dealt with in their appropriate places at the beginning of this Outline. It only remains to mention that certain Insects and Potamonid Crabs have a habitat closely associated with the banks and beds of rivers. The Gryllid *Tridactylus* is often found in great abundance in burrows in damp soil along large rivers and *Gryllotalpa africana* in moist sand of river-banks. In shallow rivers, particularly where there is a sandy bottom, Dragon-flies (*Ischnura*, *Agriocnemis* and *Onychogomphus*) are common, so are May-flies (*Anagenesia robusta*, *Polymitarcis indicus*) Caddis-flies (*Parasetodes bakeri*), and Water-beetles (the Dytiscid, *Laxophilus solutus*, the Gyrinid, *Orechtochilus gangeticus*, and the Hydrophilid, *Berosus fallax*).[1]

Estuarine Fauna (Plate VII).

The study of the estuarine fauna of rivers (such as that of the Ganges) has been of the highest scientific value from the point of view of the evolution of freshwater forms from marine ancestors. The comparatively low salinity of the waters of the Bay of Bengal which is constantly being diluted by the great freshwater effluents such as the Salween, the Irrawady, the Ganges, the Brahmaputra, the Mahanadi, the Godavari, the Kistna, and

[1] For these and other notes on the Insect fauna of various habitats the author is indebted to Mr. S. Rebiero, Entomological Assistant, Zoological Survey of India.

the Cauvery, and the gradual changes from the markedly less saline waters of the Bay of Bengal to the freshwaters of the rivers beyond tidal limits facilitate along these highways the immigration of marine forms into freshwaters by gradual adaptation to the transitional conditions of existence in the estuaries. The few observations that have been made in the river estuaries such as those of the Mahanadi, Indus, and Irrawady show that the character of the estuarine fauna in these rivers is essentially similar to that of the Ganges. In the muddy creeks and estuaries of the Gangetic delta a large variety of animal forms belonging to nearly all the more important groups of the animal kingdom except Echinodermata has been found. Many of the genera represented are either marine or brackishwater in origin, specialized or adapted to life in such situations as the mud-laden turbid waters, or the soft ooze-like bottom, or the tidal mud-flats (open or covered with mangrove) which are characteristic of the Gangetic delta. In these environments are found Sponges (Clionidæ and Suberitidæ) of distinctly marine origin, Hydrozoans (*Dicyclocoryne*, *Annulella*), Scyphomedusan jelly-fishes (*Netrostoma*, *Acromitus*), Actiniarian sea-anemones (*Edwardsia*, *Halianthus*, *Pelocœtes* and other Halcampactiids), Polychætes and Echiuroids (Nereidæ, Spionidæ, Capitellidæ and other families, and *Thalassema*), the pelagic *Sagitta*, Mollusca (Neritidæ, Littorinidæ, Assimineidæ, Auriculidæ, Rissoidæ, Nassidæ, Cerithidæ, Onchidiidæ, Cyrenidæ, and Mytilidæ) of brackishwater or marine origin, Polyzoa (*Barentsia*, *Loxosomatoides*, *Victorella*, *Bowerbankia*, and *Membranipora*) of brackish water origin, Crustacea (Entomostraca, Amphipods of the genera *Quadrivisio*, *Grandidierella*, Mysids such as *Potamomysis* and *Macropsis*, Penæid and Palæmonid prawns, Hymenosomatid, Portunid, Grapsid, and Ocypodid crabs), the King-crab (*Carcinoscorpius*), anadromous fish like the Indian herring, *Hilsa ilisha*, estuarine fish of the Siluroid group (Pangasiidæ, Ariidæ, Plotosidæ), the Herring and Gobies (Clupeidæ and Gobiidæ), and the Sting-rays (*Trygon*) of marine or brackishwater origin. Some of the forms enumerated above live in the ooze-like bottom mud, some live in burrows in thick mud between tide-marks or crawl on the surface, while others are active swimmers in muddy water. Certain adaptations to life in muddy waters, such as degenerate eyes, highly developed tactile organs, absence of bright colours except those of pink or red, the occurrence of resting buds and highly resistant non-sexual reproductive bodies are among those observed in certain groups of animals living in the Gangetic delta. The remarkable superficial resemblance of some of these specially adapted forms [Fish and Crustacea, which Kemp (1917) observed] to the deep-sea inhabitants of the same groups is a typical case of similar physical conditions (soft muddy bottom and low visibility) in different environments producing the same type of adaptation. Recent researches in estuarine waters have shown that the salinity of

bottom water in river estuaries is nearly the same as that of the sea and facilitates the penetration of bottom-living marine forms into the estuaries.

Backwater Fauna

The constituents of this fauna are as varied as those of the estuaries. There are several backwaters, lagoons and salty marshes on both the coasts of Peninsular India. The Salt Lakes of Calcutta (which are now almost fresh), the Chilka Lake on the Orissa Coast, the Vizagapatam backwater (now converted into a harbour), the backwaters of Pulicat, Ennur, and Adyar on the Madras coast, the extensive backwaters of Travancore, Cochin and Malabar on the west coast of India, and the broad barren sandy depression of land and water, the Rann of Cutch constitute the more important and well-known backwaters of India. They are more or less connected with the sea either temporarily or permanently by means of short channels or tidal creeks, and during the rainy season floodwaters enter them in such large quantities as to convert them into freshwater lakes. The fauna of these backwaters, as in the case of the Chilka Lake, is mainly of marine origin although there is a strong estuarine element as in the Gangetic delta. Apart from occasional immigrants into the Chilka lake from the sea and the adjacent freshwater areas the permanent inhabitants of the lake though not rich in species are found in large numbers and are capable of adapting themselves to the physical changes in their environment. With the exception of Echinoderms and Cephalopods, Pteropods, Cubomedusæ, and stony corals all other groups of the animal kingdom are well-represented in the various types of environment of the lake, such as the bottom of sand or mud or of both, the rocks, amongst weeds, and the mid- and surface-waters. The Salt Lakes of Calcutta although gradually becoming more and more fresh have a fauna which is distinctly estuarine in origin. Only a few species have established themselves in these lakes but the number of individuals of each species is very large. Among the commonest species found between 1926 and 1933 were Molluscs (*Melanoides lineata, Stenothyra deltæ, Modiola striatula, Cuspidaria annandalei*), Crustacea (*Varuna litterata, Palæmon lamarrei, Caridina nilotica, Mesopodopsis orientalis* and various Calanoid and Cyclopoid Copepods), and Coelenterates (*Phytocoetes gangetica* and *Campanulina ceylonensis*). The Pulicat Lake on the Madras coast was once an open bay but is now land-locked, and the occurrence of such genera as *Ostrea, Mactra, Arca, Murex* and *Calyptrea*, and *Balanus*, among Molluscs and Crustacea, *Polydora*, among Polychætes, and *Sycon* among Sponges shows that the fauna is entirely of marine origin. The Ennur and Adyar back-waters and those on the west coast have more or less similar features and are inhabited by a large number of marine and brackishwater forms. Amongst the latter are several interesting and perhaps

endemic species belonging to the groups Actiniaria, Annelida, Polychæta, and Mollusca.

Pond Fauna

The constituents of this fauna belong generally to certain widely distributed families and genera in the Indian Empire, and the genera and species which occur in a pond vary only slightly in different parts of the Indian Region. Amongst the small animals which occur in a pond with a muddy bottom and aquatic vegetation may be included snake-headed fish (*Ophicephalus*), Cat-fishes, Carp-minnows (*Puntius*), Top-minnows (*Panchax*) and other Cyprinodontid fishes, Perches, Ditch-eels (*Mastacembelus*), Turtles (*Trionyx*), and Frogs (*Rana*); Insects such as the Libellulid and Aeschnid dragon-flies, the Neuropterous *Sisyra indica* the larvæ of which commonly live in the canals of Sponges, May-flies (*Cœnis perpusilla*), Water-beetles, *Hydaticus vittatus* and *Cybister confusus*, the Gyrinid, *Dineutes indicus*, and the Hydrophilid, *Hydrophilus olivaceous*, aquatic Bugs and Water-scorpions (*Corixa*, *Nepa*), Caddis-worms (Trichoptera), Blood-worms (Chironomidæ), Mosquito-larvæ (Culicidæ); Water-mites (Acari); various Mollusca (*Lymnœa*, *Indoplanorbis*, *Gyraulus*, *Melanoides*, *Viviparus*, *Bithynia*, *Corbicula*, *Sphœrium*, *Potomida*, *Indonaia*, and *Lamellidens*); Polyzoa (*Hislopia*, *Lophopodella* and *Plumatella*); Leeches and Oligochæte worms; Crustacea (Potamonid crabs, Palæmonid prawns, Ostracods, *Cyclops* and *Daphnia* among Copepoda and Phyllopoda); various species of Wheel-animalcules (Rotifera); Sponges (*Spongilla*); *Hydra vulgaris*, and various Protozoa (chiefly *Amoeba*, *Vorticella* and other Ciliates, and a few Flagellates).

Lake Fauna

There are a few lakes, both in the plains and on the hills of the Indian Empire, of which the fauna has been investigated. The Manchar Lake of Sind in N.W. India, the Loktak Lake of Manipur in Assam, the Inlé and the Indawgyi Lakes of Burma are the only freshwater lakes of any large size. The animals found in these do not constitute a true lacustrine fauna, because of the admixture of a large paludine element in it. The lakes of India proper, namely the Manchar and the Loktak, have generally a poor fauna the members of which are not specialized, but the most abundant species are those of Fish and Molluscs. In the Burmese Lakes on the other hand the fauna is remarkably rich, more particularly in regard to Fish and Molluscs, both of which include peculiar and apparently endemic forms. In the Inlé Lake (Annandale, 1918)[1] representatives of nearly all the freshwater groups of the animal kingdom are present. Amongst the forms peculiar to the Lake may be mentioned the Turbellarian (*Planaria burmœnsis*), the Temnocephaloid (*Caridinicola*), the Crabs and Prawns (*Potamon curtobates*, *Palœmon naso*), several

[1] *Rec. Ind. Mus.*, XIV (1918).

aquatic Rhynchota (Notonectidæ, Corixidæ and Hydrometridæ), the Molluscs (*Lymnæa shanensis*, *Hydrobioides* and the Viviparid *Taia*), the Fish (*Barbus schanicus*, *Sawbwa resplendens*, *Microrasbora erythromicron*, *Mastacembelus oatesii* and *M. ocellatus*). In the Indawgyi Lake (Prashad and Mukerji, and Rao, 1929) on the other hand the fish fauna is fairly rich and the Mollusca are poorly represented. Amongst the fish, the Silurid, *Olyra horai*, the Cyprinid *Barbus sewelli* and *B. myitkyinæ*, and the curious pipe-fish like *Indostomus paradoxus*, and amongst the Molluscs, *Viviparus indawgyensis* and *Lymnæa decussatula* are the only endemic species present. One chief characteristic of the true lacustrine fauna of the Burmese Lakes is the occurrence of a large number of individuals of the endemic species.

Littoral and Beach Fauna.

It is somewhat difficult to give a generalized account of the fauna of the sea-coasts owing to the great variety of habitats. There may be long stretches of sand, or of sand and mud, broken up by creeks or swamps as on the east coast ; or the coast line may be rugged and rocky as on the Bombay coast. Fringing reefs in shallow water occur along the Gulf of Manaar, the Mergui Archipelago and the islands of the Andaman and Nicobar groups. In some places, as along the west coast of the Andamans, the reefs may have a formation not unlike that of a Barrier Reef. Atolls are characteristic of the Laccadive and Maldive groups of islands. The fauna of the sand and mud along the coasts consists of animals which burrow or live in burrows, and those that run or skip—Actinians (*Phytocœtes*, *Cerianthus*), Alcyonarians (*Virgularia*), Echiuroid worms (*Thalassema*), Sipunculoid worms (*Sipunculus*), Polychæte worms (Capitellidæ, Spionidæ and Ariciidæ), various Crabs (the Mole-crab *Hippa asiatica*, the Calling-crab *Uca annulipes*, and other species of *Scopimera*, *Dotilla*, *Macrophthalmus*, *Ocypoda*), Molluscs (*Harpa*, *Solen*, *Potamides*, *Pyrazus*), the Lancelets (*Dolichorhynchus*, *Branchiostoma*), and the Gobies—*Periophthalmus* and *Boleophthalmus*. A few insects (biting sand-flies, the carrion-eating Dipterous *Sarcophila cinerea*, the beetle *Cicindela biramosa*), the Hermit-crabs, *Coenobita*, *Birgus latro* (on the Sentinel Islands only), and the land-crabs, *Cardiosoma*, *Pelocarcinus*, *Geograpsus*, etc., usually haunt the sea-coast in search of food. The fauna of the coral reefs up to a depth of 1 fathom is perhaps the most varied and interesting from the point of view of the Invertebrate fauna and includes representatives of nearly all the groups of marine animals. Here one may find various forms of corals (Astræidæ, Madreporidæ and Poritidæ), encrusting Tetraxonid and other Sponges, Alcyonarians (*Alcyonium*, *Telesto*), Actinians (Phelliidæ and Sagartiidæ), various Echinoderms (*Holothuria*, *Synapta*, *Astropecten*, *Pentaceros*, *Ophiothrix*, *Temnopleurus*, *Echinometra*, etc.), tube-forming and free-living Polychætes, encrusting Polyzoa,

boring Sipunculoid worms (*Physcosoma*, *Aspidosiphon*), Turbellarians, various Mollusca (Chitons, Limpets, Trochidæ, Neritidæ, Littorinidæ, Cerithidæ, Cypræidæ, Nudibranchs), Crustacea (various Decapod crabs and prawns, lobsters, Alphæids, locust-shrimps, etc.) the Spider (*Desis inermis*), and the composite Tunicates (*Botryllus*, etc.). On rocks between tide-marks or at greater depths the fauna consists of various Hydroids, Actinians (Actiniidæ, Discosomidæ, Coralliomorphidæ, etc.), encrusting arborescent (*Dendrophyllia*) and solitary corals (*Heterocyathus*), Alcyonaria (*Spongodes*, *Pteroides*), Echinoderms (*Salmacis*, *Actinometra*, *Ophiocoma*, *Palmipes*), tube-forming Annelids (Serpulidæ), sedentary and boring Molluscs (Vermetidæ, *Lithodomus*), Crabs (Grapsidæ, Xanthidæ, etc.) and the Blenniid fish *Andamia*. The sea-weed fauna is almost as varied as that of the reef or rock fauna and includes Hydroids, small Actinians and Sponges, encrusting Polyzoa, small Nudibranchs, Amphipods, Oxyrhynch and Dromiid Crabs, and Pycnogonids. In rock pools one may find the corals *Porites* and *Meandrina*, the brittle star *Ophiothrix*, various Crustacea such as *Grapsus*, *Cryptodromia*, *Thalamita*, *Alphæus*, etc. and amongst fish the perches (*Pristipoma*, *Therapon*), grey mullets and eels.

ANIMALS WITH A RESTRICTED OR LOCAL DISTRIBUTION.

Before closing this Outline reference must be made to certain rare and interesting elements of the Indian fauna which have a more or less restricted area of distribution. Among these may be mentioned the Onychophoran, *Typhloperipatus williamsoni* (Kemp, 1914) found in chinks and crannies under large stones in scrub jungle at the foot of the Eastern Himalayas in the Abor country, the freshwater Littorinid *Cremnoconchus syhadrensis* which occurs at the edge of water falls at Khandalla in the Bombay Western Ghats (Hora, 1926), the Succineid *Lithotis rupicola* living in a similar habitat at Khandalla, the Aetheriid Bivalve *Mulleria dalyi* found hitherto only in the Kadur Dt. of Mysore State, the freshwater Medusa, *Limnocnida indica* (Rao, 1932) found in the smaller streams of the Upper Kistna river system on the eastern slopes of the Western Ghats, and the limbless Cæcilian, *Herpele fulleri* (Alcock, 1904) found only in the Cachar Dt. of Assam. Of these, the Molluscs are found nowhere else, and the occurrence of a Littorinid on the wet spray-covered cliffs of Khandalla far from the sea with a gill and a branchial chamber, and breathing unlike any known Pulmonate or Prosobranchiate Mollusca is indeed a remarkable fact of distribution. The Medusa has its closest relations in the freshwater lakes and rivers of Africa and China, while the only Indian representative of Onychophora from the E. Himalayas has close affinities with the Malayan species on the one hand and the Neotropical species on the other. The other species of the Cæcilian genus *Herpele* have been found only in W. Africa and the Panama region of America.

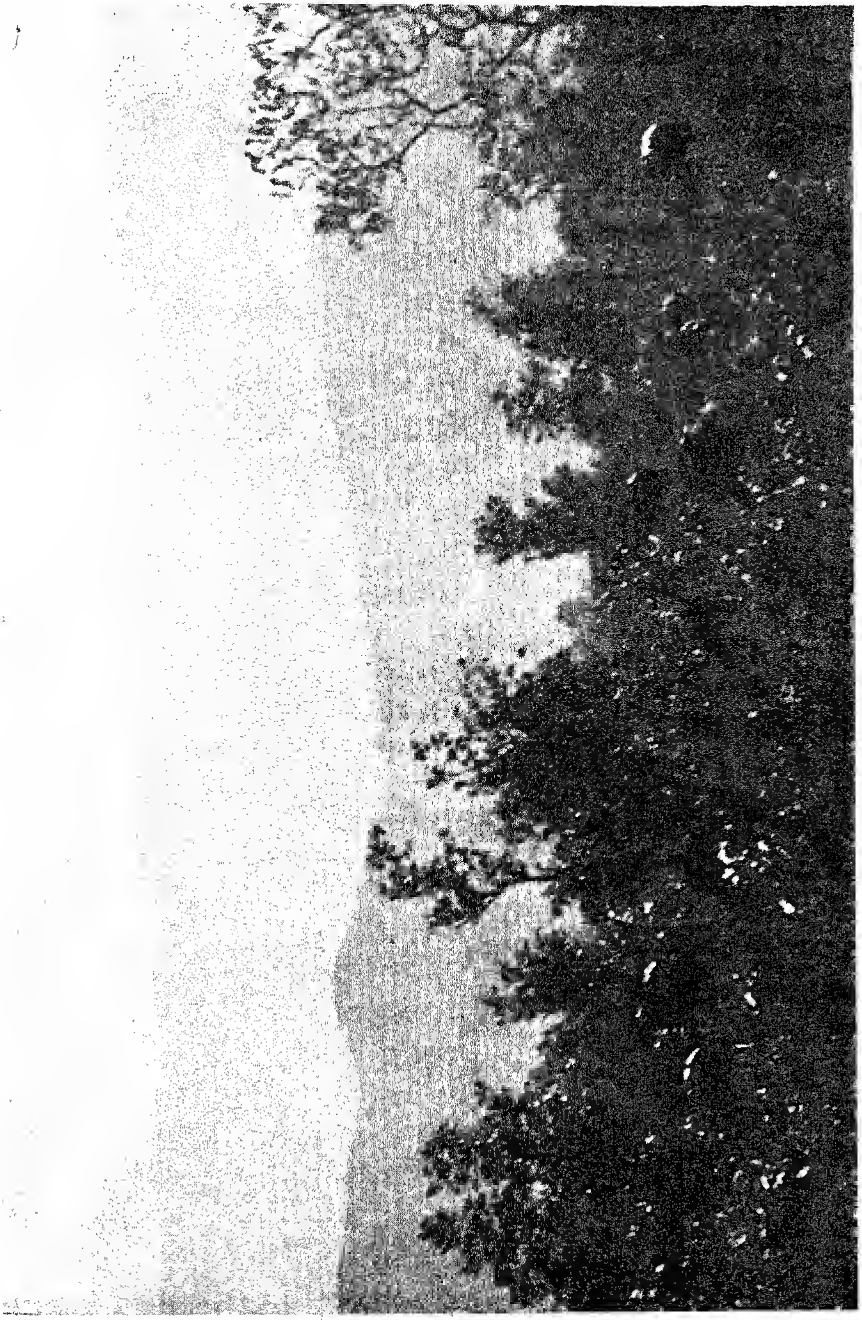
EXPLANATION OF PLATE V.

Sparse jungle in Burma with a herd of Bison (*Bibos gaurus*).

(See pp. 94–101 of the text for details of the fauna characteristic of sparse jungles in the Indian Region.)

Reproduced by courtesy of Bombay Natural History Society.

RAO: *The Fauna of India.* PLATE V.



EXPLANATION OF PLATE VI.

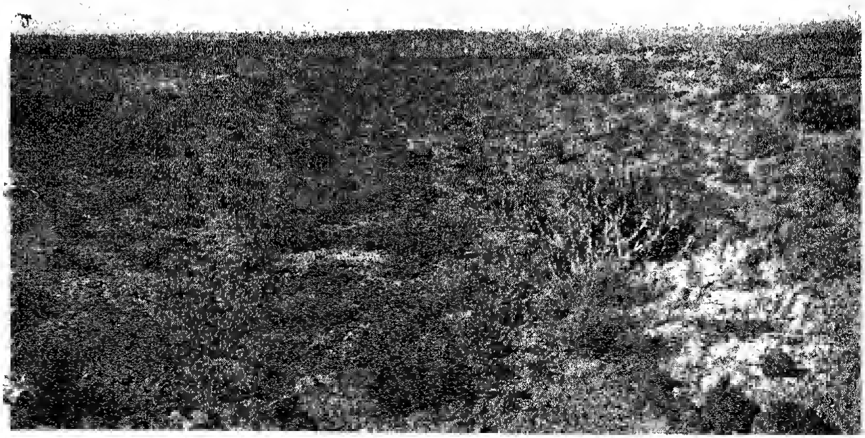
FIG. 1.—Desert tract of Sind.

(See p. 117 of the text for the fauna characteristic of desert tracts.)

FIG. 2.—Water-fall and hill-stream, Khasi Hills, Assam.

(See p. 118 of the text for details of the hill-stream fauna.)

Both illustrations reproduced by courtesy of Bombay Natural History Society.



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EXPLANATION OF PLATE VII.

FIG. 1.—Palm-fringed brackish water mud-flat, Sundarban.

FIG. 2.—Sundarban estuary of Malancha River, Bengal, at high tide.

(See pp. 119–121 for details of the fauna characteristic of estuaries.)

Both illustrations reproduced by courtesy of Bombay Natural History Society.

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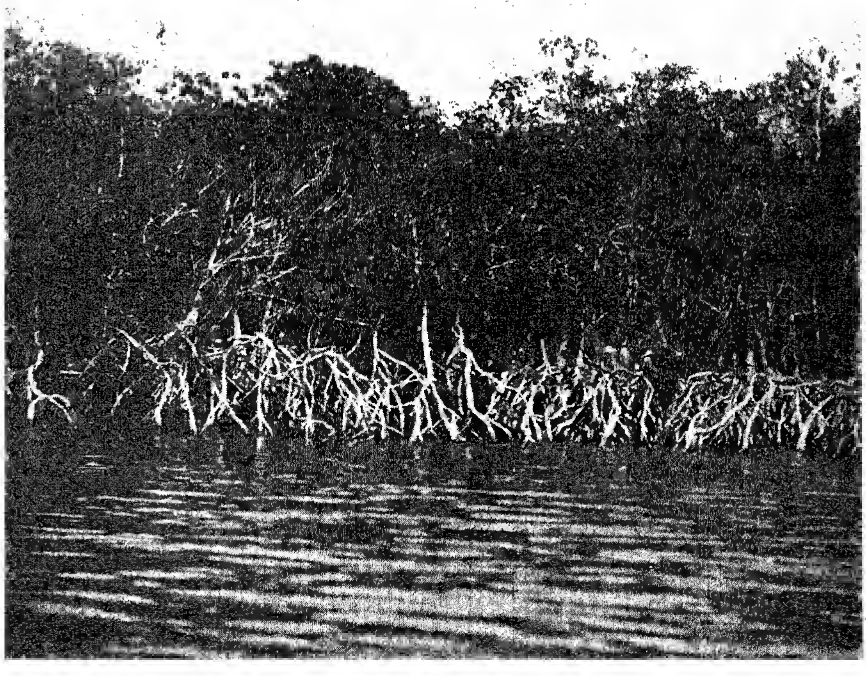

AN OUTLINE OF THE RACIAL ETHNOLOGY OF INDIA.

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Contents.

Introduction : Pre- and Early-Historic Cultures and Races.

The ethnic composition of the people of India, consists, as elsewhere, of several racial strains, which came independently at different periods—from the Palæolithic to the Recent Historical times. Of the movements of Early Man we possess no direct evidence as to the regions from which he came, but in the control exercised by India's topographical conditions in directing racial movements into the country, we have some unmistakable pointers regarding the sources of these drifts. No racial invasion could have taken place from across the seas before the art of navigation was acquired by Man, and the mountain barriers on the North were likewise impassable. Man therefore could only have reached this country through the gaps in the mountain chains on her western frontiers. On the eastern side, the dense forests and the difficult mountain passes make it less probable for Early Man to have used these routes in any considerable extent. Very few artifacts as relics of Early Man's handiwork, have so far been recorded from these parts, but in the heart of the country itself, specially in

Central and Southern India, along riverbeds and hill terraces, crude and polished stone implements have been found in great abundance. But until recently we had no stratigraphic evidence of the age and culture-sequences of the Stone-Age Man in India. The Yale-Cambridge-India Expedition, which recently surveyed the Pleistocene in Kashmir and North-Western India, has not only found ample evidence of human occupations from the Early Palæolithic to the Late Neolithic times, but has also been able to at least tentatively fix their chronology by correlating them with the glacial cycle in the Kashmir regions. It appears that there were four major glaciations in the Himalayan regions with three interglacial periods. The earliest relics of human occupation such as 'rolled flakes and well-worked hand axes' closely resembling those belonging to the Acheulean Culture of Europe were found in the 'boulder conglomerate stage', about the end of the Second Ice advance. This hand-axe culture was replaced by another which appeared after a long erosion interval and lasted from the Second Interglacial to the Fourth Glacial Periods, and very appropriately named the 'Soan Culture' by de Terra from the presence of a large number of sites in the Soan Valley. This is essentially a flake culture and is typographically allied to the Moustierian flake industry of Western Europe. Over the remains of the Soan Culture abundant evidence was discovered of Microlithic, Proto-Neolithic and early Neolithic industries akin to that of North Europe and having also some resemblance to the Upper Palæolithic Cultures of North Africa. De Terra's Survey was fruitful in another direction also. In the excavation of the Megalithic site at Burzahom, near Srinagar in Kashmir, he discovered in the lower strata (Late Neolithic), a black varnished ceramic ware identical with those found in Mohenjo-daro. His investigations, therefore, not only carried the prehistory of Man in the Indus Valley to the beginning of lithic industries, but has provided, what may prove to be the link connecting the Neolithic and Chalcolithic Civilizations of India. De Terra's and Teilhard's Survey of the Narbadda Valley and the Palæolithic site of Khandivli, about 20 miles from Bombay, showed further the extension of the Lower Pleistocene and the Soan Cultures of the Indus Valley to these regions, proving if proof was needed, that the Palæolithic man must have entered India through the North-West, and spread gradually throughout Central and Western India. It is also probable that the Stone Age cultures of Southern India were only extensions of those of the Narbadda Valley.

Unfortunately however, no trace of the skeletal remains of Early Man associated with these finds, has so far been discovered in any part of India enabling us to judge his physical type and of his possible affinities with the Stone Age races of Europe and other parts of Asia. Indeed with the exception of the fossil skull found at Bayana, but which is of uncertain antiquity, the skeletal remains

that may definitely be considered as providing landmarks in the racial history of India, are those belonging to the Indus Civilization between the third and the second millenia B.C., and the remains of the monks etc. at the Dharmarajika Monastery at Taxilla which was sacked by the White Huns in the Fifth Century A.D. The innumerable ruins of a Megalithic character, which are strewn all over Western, Central and Southern India, undoubtedly treasure a wealth of skeletal materials but with the exception of a small number—and these mostly by European Explorers—very few of these ruins have so far been excavated.

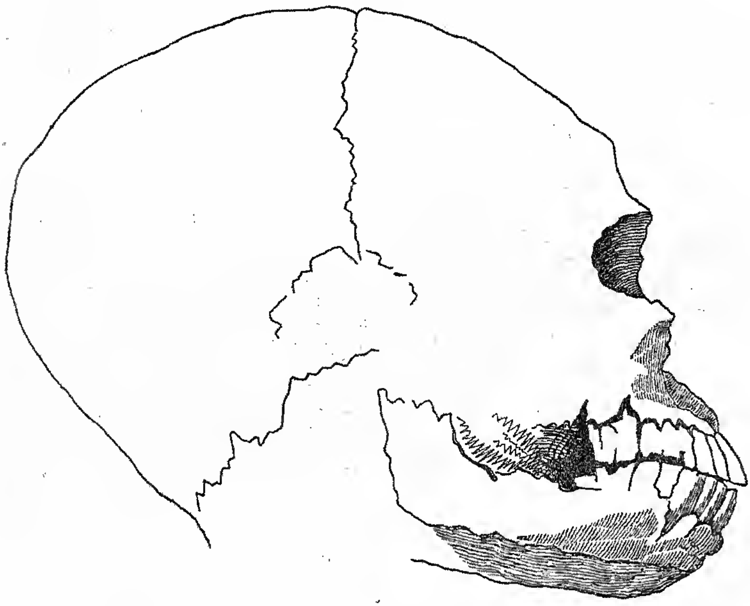
If we consider the skeletal remains during the Chalcolithic times, the population of the Indus Valley consisted in the main of moderate statured people with long head, narrow prominent nose and long face, but not physically very powerful. There was also present another long-headed type, very powerfully built and possessing a tall stature. They had stout eyebrow regions and were very large-brained—the average cranial capacity being higher than that of the modern European. A characteristic feature of this race was the enormous growth of the post-auricular parts of the skull, forming in some cases more than half of the total cranium. In addition to these two long-headed strains, there was a distinctly broad-headed element with high cranial vault and prominent nose. The back of the skull among this type varied from a round to a vertical flat shape of the Armenoid Race. All these three groups also occurred in ancient Al-Ubaid and Kish, showing that the racial strains of pre-Sargonic Mesopotamia and the Indus Valley during the Chalcolithic times, were closely allied.

The prehistoric sites so far excavated in Central and South India, are all associated with Iron, and are probably of a much later date. From one of these sites only, namely that of Aditanallur in the Tinnevelly district of the Madras Presidency, several human skeletons have been recovered. In the rest, the evidence available is very scanty, either because the excavators were not acquainted with the scientific technique employed in the preservation of bones or that they did not consider them to be of sufficient importance to preserve!

The majority of the skulls from Aditanallur discloses a dolichocranial and mesorrhine type not unlike the one which underlies, in a large measure, the present Indian population. The late Prof. Elliot Smith, who examined some of the better preserved specimens from the Madras Museum, noticed a definitely Australoid and an Armenoid strain among them. Lastly Meadows Taylor, who was one of the earliest investigators of the Megalithic monuments of South India, has published the drawing of a skull from the famous ruins of Jewurgi showing pronounced negroid characteristics.

Of the early historical period our materials are mainly confined to the human remains discovered at the Dharmarajika Monastery

at Taxilla which was sacked by the White Huns about the end of the 5th Century A.D. The racial type disclosed here is also long-headed but possessing a lower cranial vault and a larger head breadth. The posterior parts of the skull are not markedly developed. The face is very long and the nose fine and highly pitched. All these traits clearly distinguish these remains from those of the Indus Valley during the Chalcolithic times, and suggest the possibility of a later racial drift.



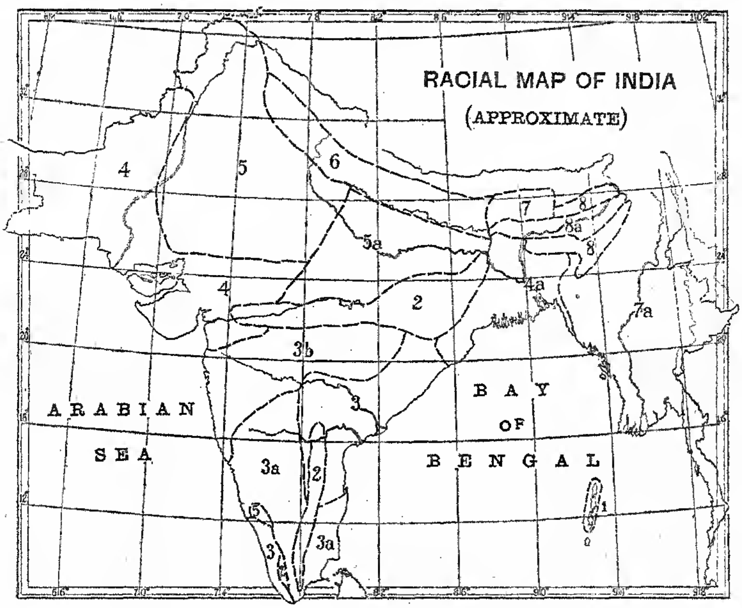
TEXT-FIG. 1.—Outline drawing of the skull from Jewurgi. Reproduced from Meadows Taylor.

These are about all the evidences we have on the racial types of Man during pre- and early-historic times in India. They are unquestionably very meagre and defective, and deal only with a small section of India's racial history. Of the rest of the early racial movements we have no information either as to the time of their advents or the precise nature of their ethnic compositions. However, such as the materials are, they nevertheless enable us to trace, at least some of the major strains in the modern Indian population, to prehistoric times.

ETHNIC COMPOSITION OF PRESENT-DAY INDIA.

The Negritos

We have no bony remains of a definitely Negrito race from any of the prehistoric burials so far excavated, but the drawing of the Jewurgi skull (text-fig. 1) from Cairn E, published by Meadows Taylor is undoubtedly Negroid. The presence of the Negrito race in the Andaman Islands and in the interior of the Malay Peninsula has been known for a long time, but in the mainland of India, its presence though suspected was hitherto not confirmed. Hutton, however, has recently shown that frizzly hair is not an infrequent occurrence among the Angami Nagas and I have drawn attention to the presence of spirally curved hair—as did also Lapique—among the Kadars and Pulayans of the Perambiculam and the adjoining Annaimalais Hills of Southern



TEXT-FIG. 2.—Racial Map of India (approximate).

1. Negritos; **2.** Proto-Australoids and Negritos; **3.** 'Basic' Dolichos and Proto-Australoids; **3a.** 'Basic' Dolichos Alpo-Dinarics and Proto-Australoids; **3b.** 'Basic' Dolichos, Alpo-Dinarics and Proto-Australoids with small elements of Orientals and Proto-Nordics; **4.** Alpo-Dinarics and Orientals with a sprinkling of Proto-Nordics; **4a.** Alpo-Dinarics and 'Basic' Dolichos with small proportion of Indus and Proto-Nordic types; **5.** Proto-Nordics and Indus with some amount of Orientals; **5a.** Indus and Proto-Nordics with 'Basic' Dolichos as a small element; **6.** Orientals and Brachy Mongoloids; **7.** Brachycephalic Mongoloids; **7a.** Short Brachy Mongoloids; **8.** Dolichocephalic Mongoloids; **8a.** Dolicho-Mongoloids with a small proportion of 'Basic' Dolichos and Alpo-Dinarics.

India. The Andamanese, as is well known, are a black pigmy race, living in the forests of the islands of the same name in the Bay of Bengal, which have sheltered them from an immemorial time, though in view of their rapid extermination, it is doubtful how long they will continue to do so. They have a dark chocolate brown skin colour approaching black, with wooly hair, often having vacant intervening spaces between little knots of hair. Their head is broad, the face round and the nose flat and broad. Steotopygia is present among women and also to some extent among men. Among the Kadars, the mean stature is slightly higher, being 1556 mm. against 1486 mm. for Andamanese males. The average skin colour is also dark chocolate brown, but not quite black. The hair is of the frizzly type, with long spirals resembling those of the Malenesians of New Guinea. Short spirals—but not of the pepper-corn type—though rare are not altogether absent. The face is short and often projects forwards with broad short noses and thick everted lips. What distinguishes the Kadars from the Andamanese however is the shape of the head. It is never truly brachycephalic as that of the Andamanese, but long, though among some of the frizzly haired men, the Cephalic index rises up to 79.29. In this respect the Kadars resemble more the Semangs of the Malay Peninsula, who are also mesocephalic, but closer still the Malenesians, who are predominantly dolichocephalic with long spirally curved hair (Plate VIII, figs. 1-3).

What exactly was the original type of the Indian Negritos is of course difficult to say. But judging from the recent discovery of Mr. Sarkar (*Nature*, CXXXVII, p. 1035, 1936) of a brachycephalic young man with clear wooly hair among the aborigines of the Rajmahal Hills of Bihar (Plate VIII, fig. 4) and the presence of mesocephals among the Kadars, it seems not improbable that the original type was not unlike that of the neighbouring Negrito tribes, specially the Semangs, who it is interesting to observe, possess a large number of designs in their combs identical with many of those used by the Kadars. It is true that at the present moment we have a few remnants only of this race in specially isolated tracts, but judging from its presence among the Angamis in the North East, Bagdis of the Rajmahal Hills of Bihar, and the Kadars of the extreme South West, it appears not unlikely that it had at one time a much wider distribution, though now submerged, excepting in these marginal areas where it has managed to survive as the last relics of an ancient race.

The Proto-Australoids

The Australoid type so conspicuous in the Tinnevelley sites in the prehistoric times and in other Megalithic remains of Peninsular India is one of the major elements in the aboriginal population of this country. A comparison of Aditanallur skulls with some of the authentic Munda crania in the collections of the Indian Museum, leaves no room for doubt that in the general shape of the cranium,

the development of the lower forehead, the depression of the nasal root, the breadth of the nasal bones and in the projection of the facial parts, the two are essentially alike.

Among the aboriginal Indian population, specially those of Central and Southern India, there are many who show a marked development of the supra-orbital ridges along with a sunken nasal root, but in the majority however, this trait is not pronounced, though in the shape of the head, the form of the nose, the projection of the face, skin colour and structure of hair no significant differences are observed.

If we compare these tribes with the Veddas of Ceylon, and the aborigines of Australia, we find that in the shape of the head and the face, the form of hair and, skin colour, the three are essentially alike, though the Australians are taller and show larger absolute dimensions of head than the other two. The Veddas are closer to the Australians, than to the Indian tribes, who are the smallest of the three. Among the Australians also the brow ridges are more marked and the body hair is more profuse. In all these characters there seems to be a regular gradation, the shortest and the smallest being the Indian tribes, then come the Veddas, and lastly the Australians. We may assume then that all the three belong essentially to the same stock, the Indian tribes retaining the more basic characters, and the two extra-Indian groups having developed some of the features in a more marked manner. The most appropriate term to apply to them therefore is *Proto-Australoid* which shows best the genetic relationships between the three (Plate VIII, figs. 5-6).

The whole of the Central and Southern Indian tribes belong essentially to this type, though pertaining to different linguistic families. The same can be said of the tribes of Western India and the partially reclaimed groups in the Gangetic Valleys who form the outer layer of the Hindu social system at the present times. The Bhils, Kols, Badagas, Korwa, Kharwar, Munda, Bhumij and Malpaharias living in the Central Indian highlands and the Chenchus, Kurumbas, Malayans and Yeruvas of South India may be regarded as some of the representatives of this race, though the amount of admixture with other types specially the Negritos, in each of these tribes is not uniform. It is certainly stronger among the tribes living in the marginal areas of S. India than among the Central Indian groups.

We have no definite evidence as to the times of the respective drifts of these races into India but judging from their distribution, the Proto-Australoids appear to be later, whose pressure it may be presumed, the more primitive Negritos were not able to withstand and were gradually driven off to less hospitable regions. In the process of this expansion, the Proto-Australoids unquestionably have absorbed a large amount of their blood in varying proportions, to which must be ascribed some of the differences

noticeable in these tribes—specially between those of the Central Indian highlands and the Southern Indian hills.

The Basic Dolichocephalic Type

One thing that comes out most clearly when the somatic characters of the people inhabiting the plains of India are compared, after the various aboriginal strains are eliminated, is the predominance of a type of medium statured, long headed people. It is characterized by high cranial vault, a narrow, vertical forehead often bulging, with the supra-orbital ridges but faintly marked. The face is short with prominent cheek bones and pointed weak chin. The nose is moderately prominent and long but the nostrils are spread out giving a low mesorrhine index. The lips are full and the mouth is large. The skin colour varies from a rich to a dark tawny brown and the eye is invariably black. The hair is straight but inclined to be wavy and is moderately present both on the face and the body (Plate VIII, figs. 9–12).

This is the type par excellence of Southern and a large component of the lower section of the population of Northern India, though among the upper classes even, it is not altogether unknown. It has been suggested that this race has evolved in the open grasslands of the Deccan out of the Proto-Australoid race mentioned before. I find this view difficult to accept for several reasons, one of which is, that it is universally acknowledged that the form of the nose has a great diagnostic value in the differentiation of races, but it has also been shown that warm and moist climate has a tendency to broaden the nostrils by 'snuffing up great quantities of warm and moist air through the nose', whereas, 'the cold air of northern climates needs to be warmed up by passing through a high narrow nose charged with blood'. If this be so, it is inconceivable how the flat broad nostrils seen among the aborigines of Central and Southern India, could become narrower and more pronounced after prolonged habitation in the hot and moist climate of the Indian plains.

A second and more weighty consideration in the close resemblance of this race with that described by Elliot Smith from the skeletons found in the Pre-Dynastic graves of Upper Egypt. Here also the type is long headed and the body long and slender. The forehead is similarly vertical and bulging with poorly developed eyebrow ridges and the nose small and likewise broad. We have no evidence as to when this race first came to India but among the crania found at Aditanallur and several of the Cairns of the Deccan, it occurs as the prevalent type. In Europe, the Megalithic monuments are assigned to the Late Neolithic times and the racial affinities of the people who introduced that culture are broadly classed as Cro-magnon. We have seen that Dr. de Terra has definitely established that in the N.-W. India, the Megalithic remains also belonged to the same times. In Central and Southern

India, on the other hand, the Megalithic Culture was associated with bronze and iron and must have been more recent. The high percentage of tin in the bronze objects of Aditanallur and the Cairns of the Deccan and Central India, shows the intimate connection between the cultures of these places, as against that of the Indus Valley where the percentage of tin is very low.

We have not found so far any remains of man in the Megalithic sites of North-Western India, but from the crania discovered at Aditanallur and the Deccan Cairns, it would seem that a race allied to the one which inhabited the Pre-Dynastic Egypt and appeared to have a wide distribution, from North Africa to the Indian frontiers in ancient times, brought this culture to India during the Neolithic times. The presence of bronze and iron objects in Central and Southern Indian sites, however indicates, that the use of these metals was learnt subsequently—probably in the Indus Valley, and with this knowledge they were able to work the easily procurable copper and iron ores, when pushed to the plateaus of Central India, and from where they gradually spread over the whole of the Deccan and Southern India, conquering and partially mixing with the older Proto-Australoid races, who in their turn had driven out and absorbed the more primitive Negrito tribes.

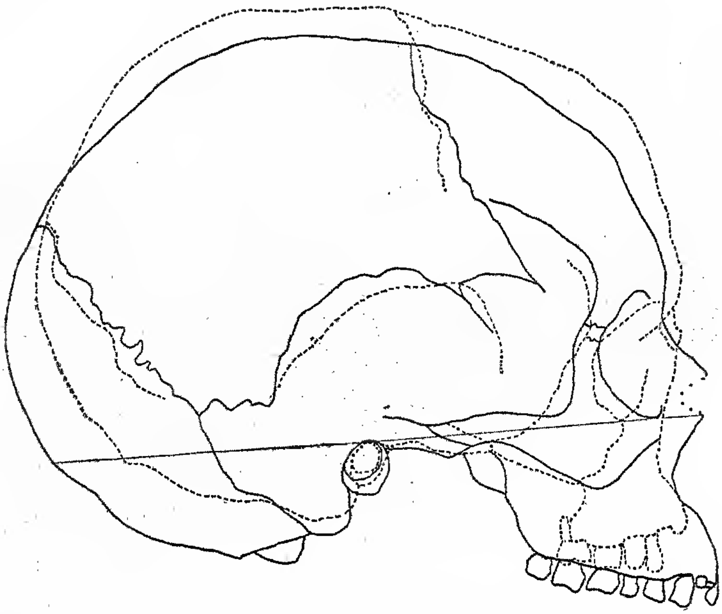
The Large-brained Chalcolithic Type

This older and more basic strain must be distinguished from the two dolichocephalic types found in the Indus Valley during the Chalcolithic times. The powerfully built large-brained race with well developed supra-orbital regions and enormous growth of the post-auricular parts of the skull, whose earliest relics are found at Mekran, the open burials of Harappa, and the lower strata of Mohenjo-daro, survives to this day in the population of N.-W. India as shown from Eickstedt's discovery of 'a coarse type with robust proportions, overhanging occiput and prominent superciliary ridges but with lighter complexion' among the Punjabi soldiers imprisoned by Germany during the War. The more delicately made smaller type with sharp well-cut features and fine narrow nose, whose remains were also found in abundance in all the sites from Nal to Mohenjo-daro, though resembling the Cairn builders of S. India in stature, slenderly built bodies and smooth eyebrow regions is nevertheless distinguished from it by more refined features, lower cranial vault, well arched forehead and narrow high pitched nose. Its affinities therefore are closer with the Mediterranean race of Europe as distinguished from the older Badarian strain with which the South Indian appears to have been intimately connected.

The Indus Type

In India this ancient 'Indus type'—to call it from the place of its earliest occurrence—seems to be later than the previous type, and as far as can be judged, responsible for the civilization

which developed on the banks of the Indus. Without doubt this early race has entered largely in the composition of the population of Northern India, specially the upper section, and provides one of the bases for that sharp distinction which marks the people of Northern from Southern India, though among the Brahmins there, and upper classes, its presence is unmistakable (Plate VIII, figs. 13–16).



TEXT-FIG. 3.—Composite profile drawings of Aditanallur 'Basic dolichocephalic' (..........) and Mohenjo-Daro 'Indus' (————) skulls, superimposed. $\times \frac{1}{2}$.

The Alpo-Dinaric Type

On the racial framework thus built there has entered from the North-west (i) a Non-Mongoloid Brachycephalic race with round and broad face and long prominent nose. The earliest evidence of this race is found at Mohenjo-daro during the Indus period. In Harappa it occurs more frequently, specially at a somewhat later date, and it is here for the first time that the plano or flattened occiput so characteristic of the Armenoid race is met with. Elliot Smith reported the occurrence of a similar type at Aditanallur, and in some of the crania excavated from the Cairns of Hyderabad by Hunt, its presence was also noticed. At the present moment

the Brachycephalic Non-Mongoloid races are dominant in Guzrat, Kanara and Bengal, and mixed with the older basic long-headed type and the Proto-Australoid races, it occurs very largely in the Maharashtra and the Tamil country. There is a certain amount of local variation in this type, that of Guzrat for instance being shorter and lighter in skin colour than the rest—but in the fundamental traits there is an essential agreement, showing that the basic type was one or closely allied. In general terms this can be described as of short to medium stature, broad high head with somewhat receding forehead, and plano or flattened vertically inclined occiput. The face is short among the Guzratis but longer in Bengal, and the long nose is prominent and often arched and convex specially in the former. The skin colour varies from a pale olive among the Nagar Brahmins and Coorgis, and light brown among the Bengali Kayastha, to dark tawny brown among the Tamil Chettis. The eyes are round and horizontal and the hair is generally straight and profuse on the face and body. In general shape and features the affinities of this type are closer with the 'Dinaric' race of Eastern Europe rather than with those of the 'Armenoid' who possess some of the characteristics in a specially intensified form (Plate IX, figs. 5–12).

The recent discoveries of Bertram Thomas have definitely established the existence of brachycephalic types in South Arabia of which the 'Omani' appears to be Armenoid. We have no evidence of its occurrence in India before the Chalcolithic times, but from then onwards it certainly had drifted along the Western littoral into Kannada and Tamil lands, leaving Malabar and Andhra unaffected. An eastward movement seems to have penetrated early into the Gangetic delta leaving a distinct trail in Central India and Bihar. No adequate reasons exist for thinking, as some have done, that the brachycephaly in the Gangetic delta is continuous with that existing in the plains of Burma. Apart from fundamental differences in the physical types in these two places, the dense forests and the mountain barriers formed by the Patkoi, Naga-Lushai, and the Arakan-Yoma Hills extending up to Cape Negrais, are formidable obstacles against any migration coming from the Burma side. The origin of the brachycephalic strain in the Gangetic delta is the same as that of Western India and is probably the result of racial movements in South-west Siberia during prehistoric times which caused similar or closely allied types to appear also in Eastern Europe and Southern Arabia.

The Proto-Nordic Type

(ii) The racial invasion which has however caused the most profound change in shaping the culture and history of India is the one associated with the advent of the Vedic Aryans somewhere in the second millenium B.C. We have no skeletal remains from ancient India which can be definitely attributed to them, but in those recently discovered in the Dharmarajika monastery at

Taxilla, we probably get some idea of their racial type though of much later times. The monastery was sacked by the White Huns in the fifth century A.D. and with the exception of one, all the human skeletons were apparently those of the monks who occupied the monastery. The features that distinguish these skulls from the other long-headed types found so far in India, are their comparative broadness, lower vault of their cranium and a mean cubic capacity as high as 1552 c.c. The nose is very highly pitched and narrow and the face well built and long. The lower jaw is powerfully made and the whole cranium and face give the impression of great physical strength. At the present moment the type is found as the dominant element throughout the N.-W. Frontiers among the various Pathan tribes, mixed with what Eugen Fischer has called the 'Oriental' race. Among the tribes living in the valleys formed by the Upper Indus and its tributaries of the Swat, Panjkora, Kunar, and Chitral it is found in its purest forms, specially in the Kaffir tribes of the Hindukush mountains. In the Punjab and Rajputana and the higher classes of Upper India it is also marked but increasingly more mixed with the two older types of dolichocephaly already mentioned. There is also a sprinkling of it in the rest of Northern and Western India but nowhere dominant (Plate IX, figs. 13–16).

Among the Northern Mountain tribes 'the milk just tinged with coffee' skin colour of the North Indian upper classes, changes into the rosy white of North Europeans and there is a good percentage of grey and blue-grey eyes, sometimes accompanied by chestnut or red hair. Robertson wrote of the golden hair among the Red Kaffir women but I have found no instance of a truly golden or flaxen hair among any of these people, but of course Robertson had a much longer and wider acquaintance with them, while my knowledge was confined to the valleys of the Rambur and Bamboret and the adjoining hinterlands. Generally speaking however, the hair among these peoples varies from a brown to a light brown colour, but occasionally one notices a reddish tint. I doubt however, if this race in India can be strictly termed 'blond' in the same sense in which the people of Northern Europe are called. They can be more accurately described as partially blond or Proto-Nordics. Eugen Fischer has stated that the upper castes of Northern India retain the Nordic characters of stature, head and the nose without the fair tint of the skin. In the hot climate of the Indian plains, the blonds were no doubt eliminated by natural selection, but if the hair colour of the Kaffir and the allied tribes now living in the cold secluded regions of the Hindukush mountains, be of any indication, the original type among the Vedic Aryans could not have been completely blond—a trait which appeared to have developed subsequently in its present form among the people living around the Baltic. The presence of light eyes among the Chitpavan Brahmans of Bombay, and in a very small degree among those of the United Provinces, Bihar and Bengal, shows that the influence of

this type extended far beyond the North-Western parts, of which traces alone now remain in the outlying regions.

The Oriental Type

(iii) In addition to this lighter element, in the whole of the North-West there is another intruding element which Fischer has called the 'Oriental'. In this the skin colour is fair but the eyes and hair are black and the nose is markedly long and aquiline. Among the Badakhsis of Northern Afghanistan this is the dominant type, and throughout the Pathan country from Dir to the Khybar it forms a strong layer. The short longheaded type which extends from Chitral to Western Nepal, and is the characteristic type of the Himalaya Mountains, appears to be a variant of this type, and must have come very early into the Western Himalayas from where it had spread all along the sub-Himalayan regions (Plate IX, figs. 1–4).

In the plains of India the 'Oriental' strain, though present, is not however strongly felt except in the Punjab where it is conspicuous among certain sections. Among the higher classes of the Moslems of Upper India, the 'Oriental' type also survives as the relic probably of the Pathan invaders, who as judged by the Badakshis of North Afghanistan must have contained this element.

The Tibetan Type

The main movements of the Mongoloid races appear, to have passed by India without affecting its population to any considerable extent, except the sub-Himalayan region, Assam, and the lands adjoining the Eastern Frontiers and Burma. The true Mongol races, as seen among the Turki speaking peoples living in Chinese Turkistan, and in and around the Taklamakan Desert, such as the various Khirgiz, Kalmuck and the Uzbeg tribes, as yet remain outside the Frontiers of India excepting the plateaus south-east of the Karakoram Ranges adjoining Tibet, where the Chiangpa have made their home. They are an intruding race of pure Tibetan origins. The more north-westerly Ladakhi also show distinct mongoloid characters such as high cheek bones and oblique slit-eyes, but contains at basis the racial strain characteristic of their neighbours, the Purigi and Machnopa, etc. which appears, as has been already remarked, to be a variant of the 'Oriental' race which settled very early in the Western Himalayas. From the Chiangpa to the Bhutan Hills north of Assam, the Tibetan strain appears as the dominant element amongst the Lahoulis, the Limbu, the Lepcha and the Rongpa, who occupy the entire mountain valleys as far east as the Bhutan Hills. The chief characteristics of this strain is medium to tall stature, round broad head and face, with high cheek bones and long flat nose. There is very little hair on the face and the body, and the skin colour is light brown tinged with a reddish tint (Plate VIII, fig. 7). In Nepal proper, the people exhibit a gradual increase of mongoloid blood as one proceeds east and northwards ; the basic type, however, bearing

to be the same Non-Mongoloid strain as in the Western Himalayas. The Gurung, Murmi and the Gurkha tribes who represent the mongoloid element are darker and shorter than the Tibetan proper, with smaller broader nose and less flat face, and represents a distinct local group.

The Dolichocephalic Mongoloid Type

The tribes living in the hills on the Northern and Eastern Frontiers of Assam represent a separate type with a head shape either wholly or with a tendency to be dolichocephalic, the transverse diameter being narrower, and the occiput protruding somewhat. In the flatness of the nose, face, high cheek bones, oblique slit-eyes and absence of hair on the face and the body, they are however essentially mongoloid, and must be regarded as a different branch of that great race which entered from South-Western China, and whose main body moved away towards the Indonesian islands through Burma and the Malay Peninsula, leaving a side-stream in the Assam Hills, such as that represented by the Miri, Bodo and the Naga tribes, and underlies the population of the Assam Valley in general, whose upper stratum however, shows traces of the non-mongoloid longheaded and possibly brachycephalic strains which introduced Hindu Culture from Upper India (Plate VIII, fig. 8).

Brachycephalic short Mongoloid Type

In Burma, the racial type again is broad headed but short and rather dark, and seems to be more closely allied to the Malays rather than to the taller and longer headed Assamese tribes. The Chakmas of the Tipperah, and the Mog tribes of the Arakan-Yoma Hills, appear to be the north-westernmost extensions of this type ; but excepting in the Chittagong districts and the strips adjoining the hills, neither of the two mongoloid strains appear to have affected the population of the Bengal plains, whose characteristic type is found in the central deltaic parts, rather than in the outlying districts.

The Oceanic Type

The above are the main strains in the racial composition of the people of Hindusthan. There were, however, some minor drifts also, one of which came from Oceania bringing the Outrigger Canoe and Cocoanut with it. Its influence appears however to have been confined chiefly to the southernmost strip of the Tamil Nad and Malabar, though it is possible that a wave of this movement reached as far north as Orissa. It is probable that this factor is responsible for the slight mongoloid strain seen among some of the peoples of these regions.

Concluding Remarks.

In the preceding pages an attempt has been made at indicating the main landmarks of the Racial History of India, and the

probable origin and distribution of the component strains which have gone to make up the Indian people. The exact contribution of each race, however, to the formation of the various types that we notice at present, is difficult to assess, as our knowledge of the factors that control the reshuffling of genes in a mixed population, to produce the various recombinations is still far from satisfactory. Similarly the distribution of the main types into separate ethnic zones is only true in a general sense, for there is a considerable overlapping of types and no rigid division is possible in many cases, though broadly speaking a zone of Proto-Nordics mixed with the Mediterranean and the Oriental in North-Western India, can be distinguished from a Peninsular Indian one containing an older and more primitive Dolichocephalic strain. On both sides of this is to be found the Plano-Occipital Brachycephalic race mixed with the types mentioned above. The Mongoloids occupy chiefly the submountain regions in the North and the East, while the dark aboriginal tribes are scattered all over the Peninsular highlands, and many parts of the Upper Indian plains.

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EXPLANATION OF PLATE VIII.

Negrito Type.

FIG. 1.—Andamanese woman.
FIGS. 2-3.—Kadars from Cochin hills.
FIG. 4.—Aborigine from Rajmahal hills of Santal Parganas, Bengal.

Proto-Australoid Type.

FIG. 5.—Chenchu from Hyderabad-Deccan.
FIG. 6.—Malayan woman from Cochin.

Mongoloid Type.

FIG. 7.—Mongol from N.-W. Tibet.
FIG. 8.—Sema Naga from the Naga hills, Assam.

Basic Dolichocephals.

FIGS. 9-10.—Tamil Brahmins of Madura.
FIG. 11.—Illuva lady from Cochin.
FIG. 12.—Telegu Brahmin of Vizagapatam.

Indus or Mediterranean Type.

FIG. 13.—Nambudiri Brahmin of Cochin.
FIG. 14.—Nair lady of Cochin.
FIG. 15.—Behari Brahmin of Patna.
FIG. 16.—Bengali Kayastha lady of Calcutta.

Figures 1, 2, 5, 7, 8, 9, 10, 11 are reproduced from the *Census of India*, I, pt. 3, 1935, by kind permission of the Home Department of the Government of India.

GUHA : *Racial Ethnology of India.* PLATE VIII.

EXPLANATION OF PLATE IX.

Oriental Type.

FIG. 1.—Kho of Chitral (N.-W.F.P.).
FIG. 2.—Bania of Rajputana.
FIG. 3.—Chatri from the Punjab.
FIG. 4.—Brahmin lady of Maharastra.

Alpo-Dinaric Type.

FIG. 5.—Kathi from Kathiawar.
FIG. 6.—Bania from Guzrat.
FIG. 7.—Parsi lady of Ahmedabad.
FIG. 8.—Kanarese Brahmin of Mysore.
FIG. 9.—Baghel Rajput from Rewa.
FIG. 10.—Bengali Brahmin of Calcutta.
FIG. 11.—Bengali Vaidya lady of Calcutta.
FIG. 12.—Bengali Kayastha of Calcutta.

Proto-Nordic Type.

FIG. 13.—Red Kaffir from Rambur (N.-W.F.P.).
FIG. 14.—Khalash from Rambur (N.-W.F.P.).
FIG. 15.—Kho from Chitral (N.-W.F.P.).
FIG. 16.—Pathan from Bijaur (N.-W.F.P.).

Figures 4, 5, 11, 13–16 are reproduced from the *Census of India*, I, pt. 3, 1935, by kind permission of the Home Department of the Government of India.

GUHA : *Racial Ethnology of India.* PLATE IX.

AGRICULTURE AND ANIMAL HUSBANDRY IN INDIA.

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CONTENTS.

INTRODUCTION.

In attempting to describe the main outlines of Indian agriculture it has to be remembered that one is dealing with the agriculture of a sub-continent with a wide range of physical and climatological conditions as evidenced by the fact that there is hardly any cultivated crop of the temperate, sub-temperate and tropical zones, which is not grown, or which cannot be grown, in some part of it. Moreover it is characteristic of the agriculture of a large portion of the country that the summer annuals of temperate climates are grown during winter and more truly tropical crops during summer. In quite important areas also the climate is so modified by altitude and aspect that crops of temperate climates are found in unexpected latitudes.

The population of India is 338 million. The total area of culturable land is about 450 million acres excluding a forest area

of 83 million acres, and the total gross cropped area sown each year approximates to 285 million acres. As might be expected, the character of the cropping is mainly determined by population and here it has to be borne in mind that the animal population of the country is approximately 310 million head of which 208 million are cattle and 97 million sheep and goats. It is therefore no surprise to find that the total area under cereal and pulse crops of all kinds is no less than 244 million acres since these are the crops that are required for the maintenance of human and animal populations. Other food crops include the following :—

	Million acres.
Sugar	4·0
Tea	0·8
Coffee	0·2
Condiments and Spices	2·0
Fruits and Vegetables, including root crops ..	4·5
TOTAL ..	11·5

All the above figures include the Indian States but exclude Burma which has recently been separated from India. On balance India (apart from Burma) is a food-importing country, its average imports of rice from Burma and elsewhere amounting to approximately 2·2 million tons per annum. Viewed as a single economic unit which it was until very recently and which it still is to a very great extent, India *cum* Burma exports approximately 1·9 million tons of food grains. It should be added that the two principal cereal crops—wheat and rice—are, from the cultivator's point of view, largely commercial crops, for it is estimated that 55 per cent. of the wheat produced enters the general trade of the country, 45 per cent. being consumed in the villages of production. Of the commercial crops the most important are cotton (25 million acres), jute and hemp (3 million acres) amongst the fibres ; groundnuts 8 million acres, linseed 3½ million acres and rape and mustard 6 million acres amongst oilseeds ; tobacco 1¼ million acres. In Appendix I will be found a table showing the total area in India including Indian States and Burma for those crops for which separate statistics are maintained but for very obvious reasons many of the minor crops have been grouped, for even a complete list of individual crops would make a volume of considerable size.

The other dominating economic factor in Indian agriculture, which re-inforces the effect of dense population, is the smallness of the holdings and their fragmented character. Generally speaking, Indian agriculture is typical peasant agriculture, the number of landless agricultural labourers being relatively small and the holdings being largely worked by the peasant and his family. Additional labour is required at certain times but a considerable proportion of this is provided by the village itself. Despite the relatively large number of animals kept, mixed farming in the European sense of the word has been little developed. The bullock is the principal

working animal though male buffaloes are also used to an appreciable extent and the greater part of the transport is also done by bullocks. Cows are maintained for the production of working bullocks as much as for milk, which in some parts of the country is largely supplied by the she-buffalo.

The dominant climatological factor in Indian agriculture is the monsoon and it is the characteristic of the greater part of the country that most of the rainfall occurs between the months of June and October, *i.e.*, in the hot part of the year, the winter being comparatively dry.

Not only is the cropping and system of agriculture dominated by the character of the monsoon, but the Indian Budget has frequently been described as a gamble in rain. The greater part of the Indo-Gangetic Plain and the whole of the head of the Peninsula are served by the main monsoon lasting from June to October. The average rainfall for the whole of India during these months is approximately 40 inches, the actual for different belts ranging from about 15 (or less) to 50 inches with some special areas with much higher and much lower precipitation. The general characteristic of the cold weather is a rainfall of 2 to 4 inches between December and March. Storms occur, mainly in North-West India, in April and May but make no serious contribution to the useful rainfall. Monsoon or *kharif* crops, as they are known in India, are produced during the period of greatest rainfall, the most important being rice, the millets, maize, a great variety of summer pulses, cotton, jute and groundnuts. This is also the principal growing period of sugarcane which occupies the land a full year. In the greater part of India the cold weather or *rabi* crops such as wheat, barley, linseed, rape and mustard are sown in October-November and harvested from March to May. These crops depend very largely on the moisture which has been conserved from the previous monsoon period supplemented by such cold-weather rain as occurs and by irrigation. In the south of India, including the greater part of the Madras Presidency and large portions of the two great States of Hyderabad and Mysore, other climatic conditions prevail. Not only are temperatures higher and conditions more truly tropical, especially on the west coast, but the bulk of the rainfall is received in what is the dry cold weather in the greater part of India, *viz.*, October to February. In these areas also the alternations of *kharif* and *rabi* crops are practically non-existent and the only crops grown are of the character of those grown in Northern India during the monsoon period. In South India, rice and millets are important food crops while long-staple cotton and groundnuts are the most important cash crops.

Irrigation.

It would be impossible for the existing cultivated area in the greater part of India to maintain its population at the present

standard of living were crops entirely dependent on rainfall. This is supplemented by irrigation and it is a commonplace that India is the greatest irrigation country in the world. Of the total cultivated area of 280 million acres no less than 60 million acres are annually irrigated on the average from one source or another. Of this area 30 million acres are irrigated from canals, 15 million from wells and 15 million from tanks, streams and other sources.

The degree to which different areas are dependent on irrigation varies considerably. The best known amongst the most modern Indian canal systems are those of the Punjab and Sind canal colonies where rainfall is insufficient to mature any crop without irrigation and where land has literally been reclaimed from the desert and converted into fertile arable cultivation. Sind indeed is practically a rainless area and there are many parallels between its agriculture and that of Egypt. As we travel south-east we reach that portion of the Punjab and the great tract of the United Provinces where canal irrigation supplements natural rainfall, permitting of an extension of the *kharif* or summer season crop, or permitting of earlier sowing (which enables plants to develop well before the heavy rains begin) and supplementing the scanty winter rainfall to which reference has already been made. Briefly it may be said that irrigation permits of at least the doubling of the yield of the winter crops and in most areas sugarcane cultivation would be impossible without it.

A word may be said about irrigation from wells as the total area irrigated from these annually is so large. Undoubtedly many of the wells are small, many of them yielding not more than 800 gallons per hour or thereabouts, so that even a comparatively light irrigation means something like 60 hours work per acre. The greater part of the water-lifting is done by bullocks though, where the wells are larger, small oil engines and centrifugal pumps are by no means uncommon. The usual water lifts are the Persian wheel and its various adaptations and the typical Indian *mhote* or *charsa* which is traditionally a leather bucket hauled by a rope over a pulley and drawn by bullocks walking down a slope. This also has many modifications.

In many parts of India, for example in Bihar and also in the Bombay-Deccan, the United Provinces and the Central Provinces, irrigation from tanks and small lakes is of quite an important character. Some of these works amount to minor canals fed by storage reservoirs on small rivers or by barrages at the necks of mountainous catchment areas. Others are of a more domestic character but all contribute to the same end, supplementing inadequate rainfall. The traditional skill in the management of some of these small water supplies is perhaps seen at its best in mountain rice cultivation where a small hill stream is successfully trained to feed successive terraces covering several hill sides with a range of elevation of perhaps a thousand feet or more.

Soils.

Four main soil types can be recognized in India, *viz.*: (1) the Red soils derived from rocks of the Archæan system which characterize Madras, Mysore and the south-east of Bombay and extend through the east of Hyderabad and the Central Provinces to Orissa, Chota Nagpur and the south of Bengal. (2) The black cotton or *regur* soils which over-lie the Deccan trap and cover the greater part of Bombay, Berar and the western parts of the Central Provinces and Hyderabad with extensions into Central India and Bundelkhand. The Madras *regur* soils, though less typical, are also important. (3) The great alluvial plains, agriculturally the most important tract in India as well as the most extensive, mainly the Indo-Gangetic Plain embracing Sind, northern Rajputana, most of the Punjab, the plains of the United Provinces, most of Bihar and Bengal and half of Assam. (4) The laterite soils which form a belt round the Peninsula and extend through East Bengal into Assam and Burma.

The great alluvial plains are characterized by ease of cultivation and rapid response to irrigation and manuring. Broadly speaking there are few soils in the world more suited to intensive agriculture so long as the water supply is assured. The other soils are less tractable and call for greater skill in management and are less adapted to small holdings; of these the *regur* soils are the most valuable.

Agricultural Implements.

As has already been said, practically all cultivation is done by draught bullocks and the capacity of these animals varies from district to district. The best types in common use are capable of handling what would be considered light single-horse implements in Europe. Reference has also been made to the importance of bullocks in drawing water from wells and in those tracts where the sugarcane is converted into *gur* (or jaggery) and not sold to modern sugar factories, bullocks are also used for crushing the sugarcane to extract the juice. Now simple three-roller iron mills are in vogue throughout the country though examples are still found of the giant pestle and mortar made of stone or wood which was the original form. Cultivating implements are few and simple. In the alluvial areas a simple wooden plough with an iron or steel point for soil stirring is the main requirement and is supplemented by a heavy wooden beam in the middle which serves the combined purpose of roller, clod crusher and soil compacter. With these two simple implements the cultivator of Northern India is able to carry out soil-moisture conserving operations with a precision which dry-farming experts of other countries might well envy. But these implements make an excessive demand on the limited bullock power and are not equally efficient for all purposes. In consequence the small iron plough has become increasingly popular during the

last quarter of a century and the number of them now in use in India runs into hundreds of thousands. Whilst the sale of such implements has been held up by the fall in prices of agricultural produce, the annual issues are still large. A good indication that these implements are in regular use is afforded by the number of spare parts sold. Originally imported and subsequently made by Indian firms these simple ploughs are now being turned out in large numbers in many parts of the country by small implement-makers. Other implements which in various areas have become important are several simple types of harrow and cultivator which are mainly of value in permitting timely work on the land and the intercultivation of crops in brief intervals between the monsoon downpours. Though on the whole the Indian peasant's time is far from fully employed both he and his bullocks often find difficulty in getting through their work at important periods of the season.

Manures and Manuring.

As regards manures and manuring, it must be admitted that India is backward. Despite the maintenance of a very large number of cattle, India is short of farm manure partly because a good deal of the cattle dung is burnt and partly because the use of litter is rare. Slowly the value of composting is being appreciated and the steady propaganda carried on by Agricultural Departments is doing something to remedy the marked deficiency in organic matter which characterizes Indian soils. In certain tracts the use of green manure is well known; in others green-leaf manure is common. Oil-cakes are used as manure in many areas, particularly castor cake which is produced in quite large quantities, as castor oil is an important lubricant for home use and is also exported in substantial amounts. The total quantity of ammonium sulphate and sodium nitrate used in India as manure now amounts to about 60,000 tons per annum, imports of potash manures amount to about 4,000 tons and phosphatic manures to about 14,000 tons. In addition, quite important quantities of phosphatic manures are produced and used in the country. Naturally the planting industries are amongst the most important users of concentrated fertilizers but the use of ammonium sulphate and oil-cakes for the more valuable staple crops and vegetables is steadily increasing though there has been an undoubted check due to the fall in prices of all agricultural commodities since 1929.

Principal Crops.

Brief mention may now be made of a few of the principal crops themselves. The rice crop (Plate X) is *facile princeps* since the total area in India and Burma is no less than 83 million acres annually when sowing conditions are moderately favourable or about 70 million acres in India alone. Rice is the principal food crop in Bengal, Bihar, Orissa, Burma, the

Rice

Central Provinces and Madras whilst in the United Provinces it is of equal importance with wheat. The total annual production of India and Burma is of the order of 32 million tons. The number of varieties is great as would be expected from the very wide range of the crop and the different conditions under which it is produced. The highest yields are obtained where the transplanting of seedlings into previously prepared puddled beds is the custom but in most provinces there is a substantial area under broadcast rice also. So far as India proper is concerned, rice is only a commercial crop to a limited extent, there being a small export of high quality rice from Bengal to the United Kingdom and Europe and from Madras to Ceylon. Burma of course is the world's greatest rice exporter and India imports annually from Burma anything up to 2 million tons of rice, mainly of the coarser kinds, to supplement internal production. In Bengal and Eastern India generally, rice is only irrigated to a very limited extent. In Madras, on the other hand, 8 million acres out of a total of 12 million acres are irrigated, the yield being correspondingly higher. Much work has been done on the improvement of rice crop by various Agricultural Departments, supplemented in recent years by the efforts of the Imperial Council of Agricultural Research and the total area under improved strains in India and Burma now amounts to 3·3 million acres.

Wheat

This is the second cereal in order of importance in Indian agriculture, the normal area being 35 million acres and production of the order of $9\frac{1}{2}$ to 10 million tons. The principal wheat-producing provinces are the Punjab, the United Provinces and Sind, in all of which wheat is an irrigated crop. The Central Provinces comes next with the substantial area of $3\frac{1}{2}$ million acres, mainly unirrigated, so that yields are relatively low. Up to ten years ago India was quite an important wheat-exporting country, export during the war period having reached as much as 1·7 million tons in a single year. Latterly exports have been less important and during the period of depressed wheat prices since 1930 have been non-existent until recently. During 1936-37 exports have been resumed and amounted to about quarter of a million tons and there are prospects of a larger total being reached during 1937-38. Wheat is grown by the Indian peasant partly as a cash crop and partly for his own food. The recent wheat marketing survey showed that approximately 45 per cent. of the wheat was used in the villages of production and 55 per cent. entered the general trade of the country. India has quite an important reserve of producing capacity and as there is every likelihood of production in North-West India and Sind responding to any permanent improvement in prices, the export of wheat from India may again become important. This crop was one of the first to receive attention from both the Imperial Department of Agriculture and the Provincial Agricultural Departments with the result that the area under improved wheats now exceeds 7

million acres of which about half is in the Punjab, about 2½ million acres in the United Provinces and over half a million acres in the Central Provinces. It is also satisfactory to note that the greater part of this large area is under half a dozen well-known improved varieties which may be mentioned Punjab 8A, Pusa 12 and Pusa 4, and the rust-resistant *sharbati* wheats of the Central Provinces. Of the total wheat area in India no less than 12·8 million acres are irrigated.

The next great group of food crops to be mentioned is the millets, the most important of these being the great millet, *Androposon sorghum* (vernacular, *juar* or *cholam*) which occupies annually about 35 million acres, the second in importance being the bulrush millet, *bajra* (*Pennisetum typhoideum*) which occupies annually an area of about 18 million acres, the total annual area under all millets being of the order of 63 million acres. *Juar* is essentially a monsoon crop in the greater part of India and the large area is due almost as much to its importance as a fodder crop as to its common use as a foodstuff in villages. *Bajra* also is essentially a village food-crop though there are substantial imports of it into some towns for use by the labouring population. The millets are generally recognized to have higher food values than rice. Plant breeding work for the improvement of these cereals is of more recent origin than that on rice and wheat but comparatively rapid progress has been made and the area under improved strains is now estimated to be 1,91,000 acres. It should be added that the great millet (*Juar*) is also grown on quite substantial scale as a special fodder crop for cutting green for the use of both milch and draught animals.

Pulses

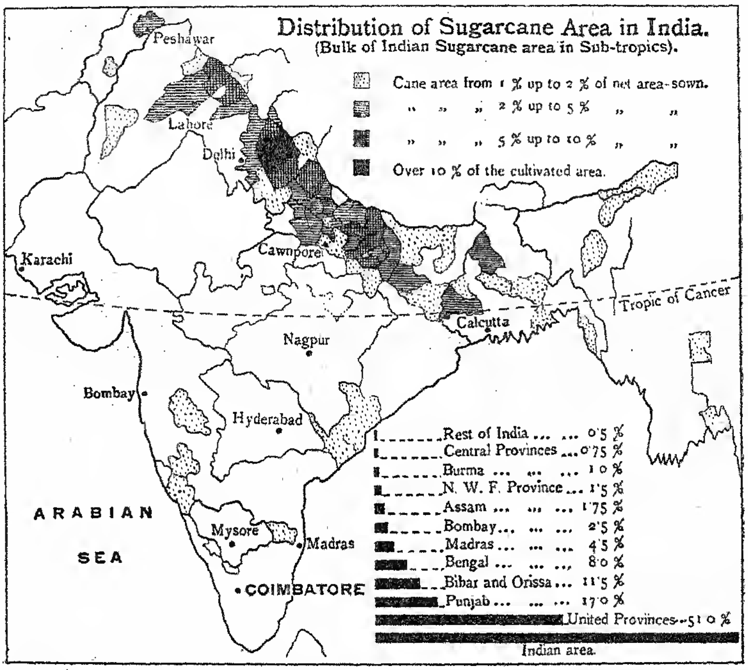
This very important group of crops accounts for practically 50 million acres annually and is trebly important to Indian agriculture. In the first place, they form the backbone of many rotations and it is due to the skilful use of leguminous crops that the present standard of fertility has been maintained in many parts of India with a minimum of manure. Their importance as foodstuffs in a predominantly vegetarian population needs no emphasis and they make an important contribution to the concentrated food supply for animals. The variety of pulse crops produced in India is very great and space will only permit mention of a few of the principal groups. One of the most important is the pigeon pea *Cajanus indicus* (vernacular *arhar* or *tur*) which is of interest in that it is grown in admixture (either broadcast or in lines) with either *juar* or cotton. Most varieties take longer to grow than either a millet or cotton and in the former case the greater part of the growth occurs after the millet crop is harvested. *Arhar dal* is one of the most important foodstuffs of the country-side. Of other *kharif* or monsoon pulses may be mentioned the following :—

Gram (*Cicer arietinum*), Peas, Lentils, and many species of *Phaseolus*.

An extremely important winter pulse is gram which occupies annually some 15 million to 17 million acres and is specially important in the United Provinces, the Punjab and the Central Provinces. It is often grown in combination with wheat, especially on the black soils of Central India and the Central Provinces. The total area under improved types of gram is now estimated to have reached 2,81,000 acres. Of recent years much more work has been done on the improvement of pulse crops but this is only just beginning to yield results so that the systematic introduction of improved strains is yet in its early stage.

Sugarcane

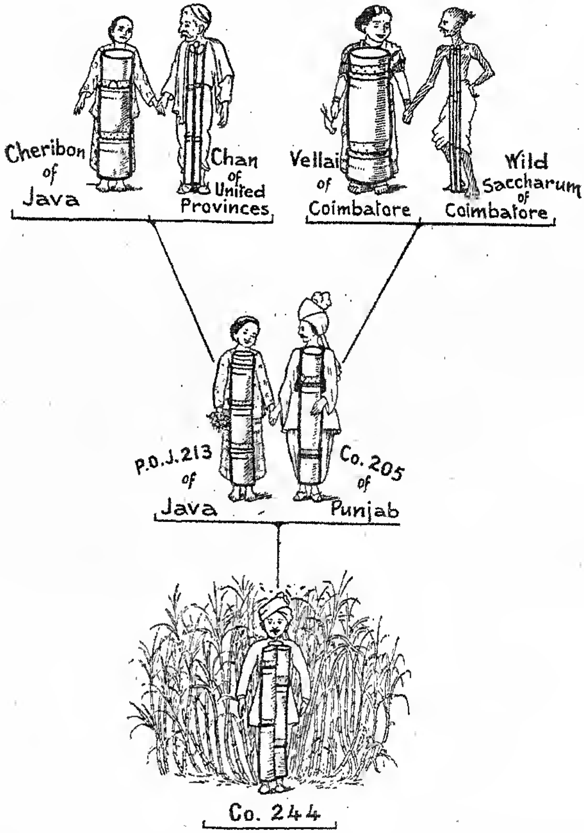
This crop forms a convenient link between the food crops and the commercial crops of India. The present area under sugarcane exceeds 4 million acres—an increase of practically 40 per cent. during the last ten years. This is due to a variety of causes of which the principal one is the establishment of a large modern sugar industry consequent on the grant



TEXT-FIG. 1.—Coimbatore (in tropical India) has successfully bred improved seedlings for the main sugarcane tracts of Sub-tropical North India.
Modified from 'Agriculture and Livestock in India', V, pt. 6, (1935).

of fiscal protection, white sugar production in 1936-37 having reached the level of 1,100,000 tons. An equally important cause is the spread into general cultivation of improved varieties of sugar-

cane which have made sugarcane production much more profitable, even with comparatively low prices for *gur* or jaggery which is the form in which two-thirds of the sugarcane is consumed. The principal sugarcane growing provinces are the United Provinces, Bihar, the Punjab, Bengal, Madras and the Bombay-Deccan and of the 137 modern sugar factories now operating 67 are situated in the United Provinces and 35 in Bihar. It is one of the special features of sugarcane growing in India that nearly nine-tenths of it is situated



TEXT-FIG. 2.—Family Tree of a simple Coimbatore Hybrid.
Reproduced from 'Agriculture and Livestock in India', VI, pt. 6, (1936).

in the semi-temperate zone and only a comparatively small proportion is grown in tropical India. The result is that the varieties of sugarcane which are most successful in India are quite different from the tropical, or 'noble', canes familiar elsewhere. The canes now in general cultivation are mainly the productions of the Coimbatore Sugarcane Breeding Station and are hybrids which

include in their parentage the wild cane (*Saccharum spontaneum*), some of the older Indian varieties and some of the best varieties of the tropics. Only in very limited parts of India have direct introductions from other parts of the world proved an economic success. The productions of the Coimbatore Sugarcane Breeding Station now occupy approximately 3 million acres.

Cotton

Of the purely commercial crops of India pride of place must be given to cotton which occupies an area of about 25 to 27 million acres with a gross production of some 6½ million bales. Of this usually 2½ million bales are consumed in Indian mills, and about 3½ million bales are exported, the remainder being used for miscellaneous domestic purposes in villages without entering into the trade of the country. India is second only to the United States amongst the cotton-producing countries of the world. Unlike America, there is no single cotton-growing belt and cotton of several distinct species and more commercial varieties is grown in the different provinces under quite varying conditions. Approximately 30 per cent. of the total cotton area in India is in the Bombay Presidency which in itself exemplifies the diversity of conditions, there being no less than four cotton-growing tracts. Grouped according to short staple and long staple and ranged under familiar trade names the annual production of cotton in India is approximately as follows :—

The Indian Cotton Crop of 1936-37 *classified according to length of staple.*

(In thousand bales of 400 lbs. each.)

Long-staple (over 1 inch).	
Punjab-American	47
Medium-staple, A. (1 inch).	
Sind-Sudhar	100
Others	47
Medium-staple, B. (7/8″ to 31/32″).	
Surti	170
Cambodia	183
Hyderabad Gaorani	141
Tinnevellies	160
Kumpta-Dharwar	100
Punjab-American	797
Sind-American	197
Others	260
Short-staple, A. (11/16″ to 27/32″).	
Central India, Malvi and Nimari	306
C.P. Oomras	107
Dholleras-Wagad	234
Broach-Kanvi	133
Others	189
Short-staple, B. (18/32″ to 21/32″).	
Khandesh Oomras	245
C.P. Oomras	666
Hyderabad Oomras	319
Dholleras-Mattheo	287
Burmas	113
Others	49
Short-staple, C. (17/32″ and below).	
Bengals-U.P.	175
,, Sind	221
,, Punjab	1,026
Others	135
GRAND TOTAL	6,307

The most compact single block of cotton cultivation is that centring on the Central Provinces, Berar, Khandesh and Central India with extensions into Rajputana, the United Provinces and even the Punjab, where the main cotton produced is of short-staple types including the various forms of *Gossypium neglectum*. Of such types approximately one million bales are consumed in the country, the remainder being exported largely to Japan. India also exports substantial quantities to the United Kingdom and the Continent. The long-staple cottons of Gujerat and part of Kathiawar, of the southern part of the Bombay Presidency and a large portion of Madras consist of the various forms of *Gossypium herbaceum*, differing in numerous important characters but closely related. The third group consists of American types (*Gossypium hirsutum*) which are the result of the acclimatization of imported types and now occupy 3½ million acres including Punjab-American, Sind-American, Dharwar Upland and Madras Cambodia cotton. These are all types of much longer staple, suitable for higher counts and are in substantial demand by Indian mills, the surplus finding a ready export market. Work on the improvement of the cotton crop has been systematic and sustained, especially since the establishment of the Indian Central Cotton Committee in 1921. The total area under improved strains now in general cultivation is 3·8 million acres. For more detailed information as to what has been achieved in the improvement of the cotton crop of India reference is invited to a separate publication by the Indian Central Cotton Committee. It is sufficient to say here that during the last 15 years a radical change in the balance between short staple and long staple cottons in India has occurred. In the typically short-staple tracts better-yielding and hardier types, which are more profitable to the grower, have been introduced and whilst in such areas as the Punjab and Sind definite new areas of long-staple cottons have been established, in the older long-staple cotton areas like Bombay and Madras the local cottons have been improved in staple and uniformity by the application of modern plant-breeding methods. The cotton crop is also unique in that for the last 15 years there has been maintained in India a Technological Research Laboratory under the Indian Central Cotton Committee. Here has been carried out systematic work on the fundamental characters which determine the quality and spinning value of cotton and also the systematic testing of new strains of cotton for Agricultural Departments in order that the most profitable types, from every point of view may be brought into cultivation.

Jute

Jute, India's other great fibre crop, is an Indian monopoly and is produced mainly in the province of Bengal and the adjoining portions of Assam and Bihar. The present area under jute cultivation is 2·18 million acres, with an estimated production of some 7 million bales. This is far below the potential producing capacity of the jute

growing districts, since, owing to the falling off in the world demand consequent on general trade depression but also due to no small extent to the development of bulk methods of grain handling, the world demand for jute fibre has fallen off. In 1926 the jute area was only just below 4 million acres and production was estimated at 12 million bales. Work for the agricultural improvement of the jute crop has mainly been devoted to the establishment of higher-yielding varieties of quality not inferior to the standard trade types. Such work has been markedly successful, the present area under improved strains being approximately 1·1 million acres. Recently an Indian Central Jute Committee, on the lines of the Indian Central Cotton Committee and financed by an annual grant of five lakhs per annum from the Government of India, has been established for the further improvement of this important agricultural industry.

Hemp

Though far less important than the two fibres previously mentioned, the two Indian hemps are of no small importance in the aggregate. Sunn hemp (*Crotalaria juncea*), the more important of the two, occupies annually an area of about 600,000 acres. Exports, which have recovered markedly during the last three years, now amount to about 33,000 tons per annum. The other variety of hemp (*Hibiscus cannabinus*), sometimes known as Roselle hemp and otherwise as Bimlipatam jute, is of more importance for local use than for world trade. Both kinds are used largely for the manufacture of ropes and twine in India. Sunn hemp is of importance from another point of view in that it is the most generally successful of the green manure crops.

Oilseeds

The oilseeds form an extremely important group of cash crops in India. The most important of them is the groundnut crop which now occupies 7¼ million acres with a production of nearly 3 million tons. This is of special interest as in many parts of India groundnut is a comparatively recent production and the extension of the area under this crop has been extremely steady, having been practically uninterrupted since 1924 when the area was less than 3 million acres. India is a great exporter of groundnuts and also a substantial exporter of groundnut oil and of groundnut cake but approximately 1,300,000 tons out of the average gross production of 2,500,000 tons (nuts in shell) is consumed in the country. Groundnut oil is an important edible oil over a large part of India; it is also the principal raw material used in the hydrogenated oil factories which have grown up in India during the last few years for the production of various vegetable substitutes for *ghi*. Work on the improvement of the groundnut crop has been in progress in Madras for some years and has recently been intensified as a result of a grant by the Agricultural Research Council. Successful work has also been carried out in the Bombay Presidency on the

substitution of a disease-resistant type for the older variety which was frequently decimated by the well-known Tikka disease.

Next in importance comes the group of Brassicae of which the most important commercial types are the rape and mustard of Northern India. These are produced mainly for home consumption. The annual area approximates to 6 million acres and production to a million tons. Exports in recent years have rarely reached the 100,000 tons mark. The oil is extremely important for food purposes whilst the cake is an important cattle food. Most of the rape and mustard produced in India is crushed in small village crushers, though an appreciable amount is handled in modern factories. Work on the improvement of this group of oilseeds is comparatively recent.

Linseed

The annual area under this crop is about 3½ million acres, the most important provinces being the Central Provinces, the United Provinces and Bihar. The annual production is of the order of 400,000 to 450,000 tons though there is reason to believe that this has been considerably under-estimated in the past. This crop is largely grown in admixture with other crops which renders an estimate of area and yield particularly difficult. On the average rather more than half the linseed produced in India is exported mainly to the United Kingdom and the Continent of Europe, the remainder being crushed in the country. Extensive research on linseed has been carried out at the Imperial Agricultural Research Institute for many years. The Indian linseeds have been completely classified, the various types isolated and the hybrids between the bold large-seeded type of the black soil areas and the small-seeded prolific type of the Gangetic Plain have been produced. Several of the hybrids have a high oil content and a medium size seed. The introduction of improved types into general cultivation has recently been undertaken.

Plantation crops

The three principal plantation crops in India are tea, coffee and rubber. The area under tea in India is approximately 820,000 acres, of which three-quarters lies in Assam and the adjoining districts of Northern Bengal, the greater part of the remainder being in South India mainly the Nilgiris. Production of tea in India is roundly 400 million pounds per annum. As is well known, tea production all over the world has been excessive and an international scheme for the regulation of the export of tea has been into operation since April, 1933. Export quotas are allotted by the International Tea Committee as a percentage of the standard year 1929-30. The current figure is 87½ per cent. In tea we have an example of a very highly organized planting industry maintaining its own scientific departments—in Northern India by the Indian Tea Association and in South India by the Tea Section of the United Planters' Association of Southern India. As a result, much valuable work has been done and a consistent policy followed over a long

series of years to the great good of the industry. It is impossible to summarize this work in any reasonable space. Of recent years the work in scientific departments of the two Associations has been mainly devoted to a study of the fundamental reasons underlying cultural and manurial methods.

Coffee

Coffee production in India is mainly limited to a part of the Madras Presidency, the State of Mysore and the small province of Coorg with small areas in the Travancore and Cochin States, the total area actually under coffee being rather over 180,000 acres. The annual total production of cured coffee is about 34 million pounds and exports in recent years have averaged 8,700 tons. India is one of the most important producers of fine mild coffee in the world. Of the total number of nearly 7,000 plantations reported over 3,000 were small plantations of between 5 and 10 acres covering about 20,000 acres in all. Coffee research is provided for at the Coffee Research Station at Balehonnur in the Mysore State which is financed jointly by the Mysore Government and the United Planters' Association of Southern India. The recently established Indian Coffee Cess Committee is mainly concerned with propaganda to increase the consumption of Indian coffee both in India and abroad and works in London through the Indian Coffee Market Expansion Board which is presided over by the Indian Trade Commissioner. The Committee has also, in co-operation with the Imperial Council of Agricultural Research, inaugurated research on the quality of coffee.

Rubber

The total area under rubber in India and Burma is approximately 226,000 acres of which 175,000 acres was tapped. About 47 per cent. of the total area is in Burma, 43 per cent. in Travancore, the remainder being in Madras, Cochin, Coorg and Mysore. Rubber exports are limited by the International Scheme for the regulation of rubber production and export.

Fruit

Statistics of fruit production in India are markedly deficient, especially as no small part of the total is accounted for by roadside trees and unrecorded small groves which are of special value to the rural population. But so far as can be ascertained the area under fruit is about 2½ million acres. Fruit research has received a marked stimulus during the last few years by grants from the Imperial Council of Agricultural Research which is financially supporting a co-ordinated scheme of work. This embraces a hill fruit research station in the Kumaon Hills of the United Provinces for work on apples and other temperate climate fruits, one for mangoes and plains fruit at Sabour in Bihar, a plains fruit research station in the Madras Presidency, a special scheme of work on citrus fruits at Nagpur with special reference to the santra type of orange, another at Lyallpur with special reference to the Malta type of orange and a scheme of experimental work on the cold storage of

fruit at Poona in the Bombay Presidency where tests are carried out for all provinces.

ANIMAL HUSBANDRY.

Reference has already been made to the large number of livestock maintained in India but unfortunately it has to be recorded that many of these are of extremely poor quality. Nevertheless the livestock industries in India are worth annually to the country no less than *Rs.1,300* crores made up somewhat as follows :—

		Crores of Rs.
1.	Cattle labour in agriculture	408·00
2.	Labour for purposes other than agriculture	127·00
3.	Dairy products	540·00
4.	Manures	180·00
5.	Other products	30·00
6.	Living animals exported (inland trade omitted)	0·24
	TOTAL ..	1,285·24

The approximate composition of India's livestock population (including Indian States and Burma), as shown at the 1935 census was as follows :—

Bulls and Bullocks	66	millions.
Cows	53	,,
Young Stock	49	,,
Total (Ox tribe) ..	168	,,
Male Buffaloes	7	,,
Female Buffaloes	22	,,
Young Buffaloes	18	,,
Total Buffaloes ..	47	,,
Total Bovines ..	215	,,
Sheep	43	,,
Goats	53	,,
Horses and Ponies	2	,,
Mules and Donkeys	2	,,
Camels	1	,,
GRAND TOTAL ..	316	,,

Diseases.

The first and greatest problem in regard to this huge population of domestic animals is the control and prevention of epidemic disease and this object has had the unremitting attention of the Imperial Institute of Veterinary Research and of provincial Civil Veterinary Departments during the last 25 years—and with very striking results. The deaths from contagious diseases in the provinces of India and Burma had

been reduced from 4,00,000 in 1925-26 to 3,00,000 in 1932-33, 2,64,000 in 1934-35 and 2,50,000 in 1935-36. Deaths from rinderpest have fallen from 2,78,000 in 1925-26 to 1,41,000 in 1934-35 and 1,38,000 in 1935-36. The latest discoveries of the Muktesar Research Institute, two methods of vaccination with a goat virus of fixed virulence, have provided an inexpensive means of conferring lasting immunity against rinderpest and, given organization and determination, there is no apparent reason why most at least of the country should not be cleared of this disease. Systematic control measures are also in operation against the other cattle plagues, *viz.*, Hæmorrhagic septicæmia, black quarter and anthrax, the necessary vaccines and *sera* being supplied by the Central Veterinary Institute. It has also been possible in recent years to devote attention to other diseases of domestic animals which though less fatal are of possibly greater economic importance than the plagues referred to above. The strengthening of the staff at the Imperial Veterinary Research Institute (including the setting up there of separate sections of pathology, bacteriology, serology, helminthology, protozoology and entomology, each under a specialist), coupled with the appointment in each province of a disease investigation officer who maintains liaison with the Central Institute has made possible a great advance. More attention has also been paid in recent years to animal nutrition both from the economic standpoint and in connection with the maintenance of health, a fully equipped animal nutrition laboratory has recently been established at Izatnagar near Bareilly for this purpose, attached to the Izatnagar Branch of the Central Veterinary Research Institute. The work carried on by Dr. Warth at Bangalore on the nutrition of Indian Cattle and the composition of Indian foodstuffs has been continued and developed. Experimental work of a similar nature, but not overlapping with the Izatnagar programme, is being carried out at several centres including Lyallpur, Coimbatore and Dacca by provincial Agricultural Departments. The question of grass land improvement has also received attention recently.

Breeding

Breeding work for the actual improvement of cattle has followed three main lines in those provinces where most attention has been devoted to it. These are: (1) The breeding and supply of suitable stud bulls; (2) the establishment of definite breeding areas where intensive work is carried out under premium bulls schemes or other suitable methods, and (3) the systematic castration of scrub bulls.

The number of approved bulls at stud in 1935-36 was approximately 10,000 an advance of 13% on the previous year but still far too small. During 1936-37 as the result of the initiative and example of His Excellency the Viceroy a great stimulus to cattle improvement has been given. It has recently been decided to set up provincial livestock improvement Boards (or Associations) which will continue to raise funds and advise on their application.

Pedigree herds of most of the more important and valuable Indian breeds of cattle (Plates XI and XII) have now been established and the following may be mentioned.

I. Milch Breeds.

Breed.	Herds maintained at
Sahiwal ..	.. New Delhi (I.A.R.I.), Manjahra (U.P.), Lyallpur, Ferozepur, Montgomery Dist., Nagpur, and Ranchi.
Tharparker ..	.. Ranchi, Patna, and Karnal.
Hariana ..	.. Karnal, Hissar, Madhuri, Khund, and Ellichpur.
Scindi ..	.. Allahabad, Bangalore, Hosur, Trivandrum, Poona and Mirpur Khas.
Gir ..	.. Bombay and Bangalore.
Kankrej ..	.. Chharodi and Baroda (Bombay Presidency).
Ongole ..	.. Guntur.
Murrah Buffaloes	.. Punjab, United Provinces and Sind.

II. Draught.

Kangyam ..	.. Hosur and Palayakottai.
Hariana ..	.. Hissar.
Dhanni ..	.. Punjab.
Amrat Mahal	.. Ajjampur (Mysore).
Khairgarh ..	.. Hempur (U.P.).
Ponwar ..	.. Hempur (U.P.).
Malvi ..	.. Central Indian States and C.P.
Gaolao ..	.. Central Provinces.
Bhagnari ..	.. Sind.
Deoni ..	.. Hingoli.

Another important step was taken during 1936-37 in the setting up of Breed Committees and the starting of a scheme for the central registration of pedigree animals of the principal milch breeds of India, *viz.*, Sahiwal, Scindi, Tharparkar, Hariana, Kankrej, Gir, Ongole, Murrah Buffaloes.

The experience of recent years has emphasized the special value of these indigenous Indian breeds. Not only are they hardy and disease-resistant but under proper conditions of feeding and management the best have reached a very satisfactory figure of milk production especially when allowance is made for the systematically high percentage of fat.

Dairying

A central dairy institute and farm mainly for the purpose of instruction in the principles of dairy-farming and European dairy methods has been maintained by the Central Government at Bangalore for many years. Funds have recently been allotted for the enlargement and development of this institute and of a branch at Anand in Gujarat to include a larger amount of experimental work and research on milk and milk products. A great immediate problem is that of a better supply of milk to Indian cities. This can only really be solved by taking cows out of the cities and sending in milk from suitable country areas. This calls for immediate experimental work on

processing and transport which will be taken up at the enlarged Imperial Dairy Institute. A report on the steps to be taken to develop Indian dairying has been made by Dr. N. C. Wright, Director of the Hannah Dairy Research Institute, Ayr, Scotland who toured through India on behalf of the Imperial Council of Agricultural Research in 1936-37 to study the problem.

In this brief note it has been impossible to give any adequate picture of Agriculture and Animal Husbandry in India but those who are interested are invited to consult the annual publication of that name issued by the Imperial Council of Agricultural Research and the annual report of that body.

Appendix I.

Area (in thousands of acres) under cultivation for principal crops.

	1930-31.	1931-32.	1932-33.	1933-34.	1934-35.	1935-36.
Rice ..	82,846	84,374	82,882	83,423	82,507	81,841
Wheat ..	32,189	33,803	32,976	36,077	34,490	33,605
Sugarcane ..	2,801	2,971	3,317	3,311	3,481	4,003
Tea ..	803	806	809	818	826	826
Cotton ..	23,812	23,722	22,483	24,137	23,972	25,994
Jute ..	3,492	1,862	2,143	2,517	2,670	2,181
Linseed ..	3,009	3,309	3,299	3,261	3,410	3,402
Rape and Mustard ..	6,632	6,220	6,094	6,034	5,338	5,268
Sesamum ..	5,618	5,639	6,256	6,307	5,230	5,633
Castor seed ..	1,457	1,583	1,617	1,534	1,448	1,447
Groundnut ..	6,579	5,489	7,409	8,226	5,766	5,784
Coffee ..	160	172	176	183	185	188
Rubber ..	192	184	180	224	225	228
Other crops ..	83,596	85,422	83,361	82,662	81,815	79,835

Appendix II.

Yield of principal crops.

Rice	'000 tons	32,198	33,001	31,114	30,907	30,238	27,902
Wheat	,,	9,306	9,024	9,455	9,370	9,729	9,426
Gur	,,	3,228	3,975	4,676	4,896	5,140	5,903
Tea	'000 lbs.	391,080	394,083	433,669	383,674	400,095	396,660
Cotton	'000 bales	5,226	4,007	4,657	5,108	4,857	5,963
Jute	,,	11,205	5,542	7,072	7,987	8,500	7,215
Linseed	'000 tons	377	416	406	376	420	384
Rape and Mustard	,,	988	1,025	1,042	943	900	954
Sesamum	,,	526	476	551	541	406	461
Castor-seed	,,	120	146	151	143	105	119
Groundnut	,,	2,766	2,268	2,997	3,330	1,884	2,228
Coffee	'000 lbs.	32,973	33,613	33,037	34,601	32,744	41,162
Rubber	,,	24,351	20,117	6,381	12,915	37,156	48,545
Other Crops	'000 tons	18,368	17,793	17,653	16,974	18,052	17,925

EXPLANATION OF PLATE X.

The Assamese cultivator and his family harvesting paddy.

Reproduced from *Agriculture and Livestock in India,* Vol. VII, pt. 4, (1937).

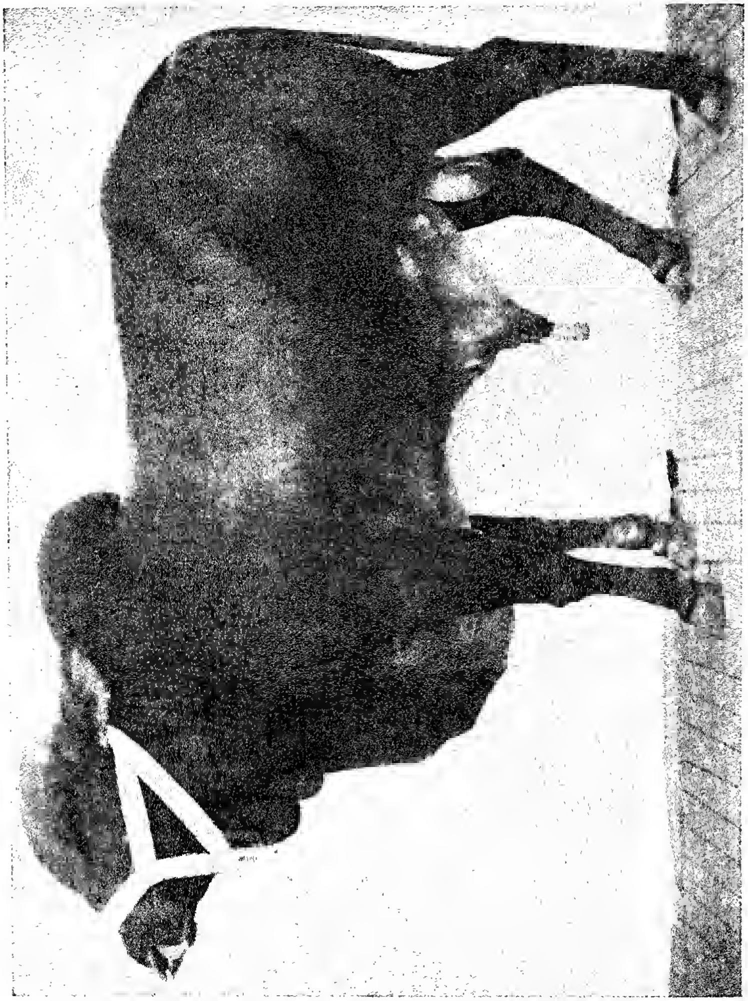
BURT: *Agriculture and Animal Husbandry in India.* PLATE X.

EXPLANATION OF PLATE XI.

Bull No. 539 Rajad; Born 12-2-1930; Sire—Raja; Dam—Adami; Dam's best lactation—7,850 lb.; Weight on 21-12-1935—1,100 lb. (Photographed on 13-12-1935).

Reproduced from *Agriculture and Livestock* in India, Vol. VI, pt. 6, (1936).

BURT: *Agriculture and Animal Husbandry in India.* PLATE XI.

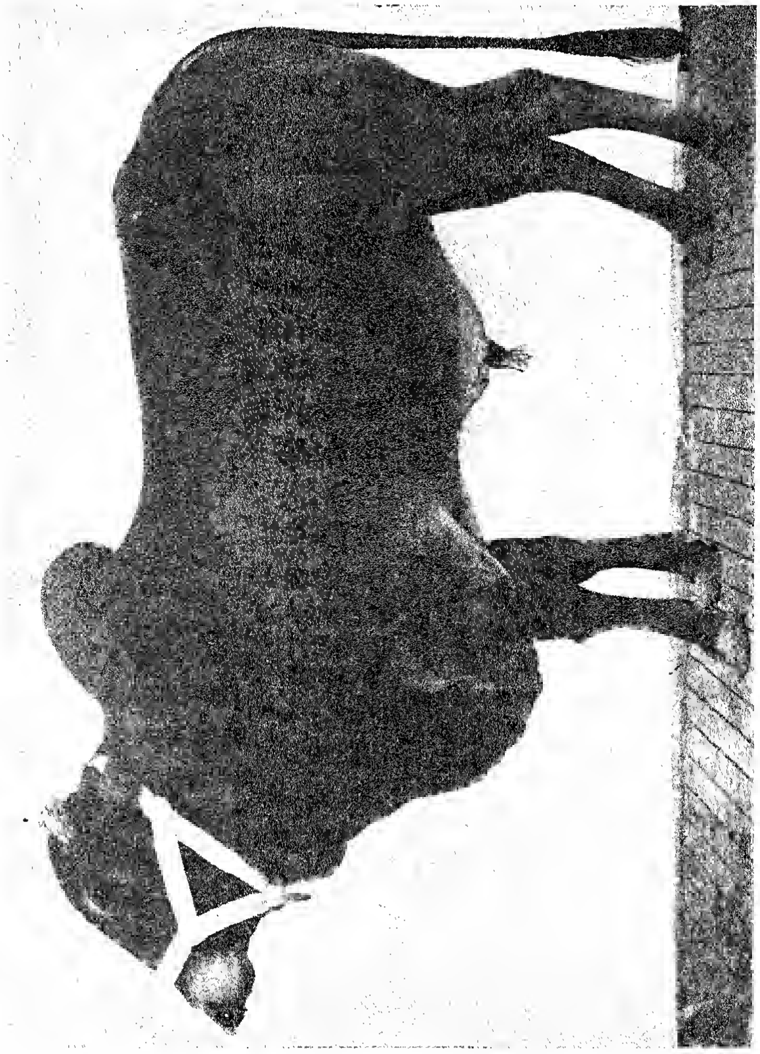


EXPLANATION OF PLATE XII.

Early maturity bull Nala No. 602 ; Born—25-2-1932 ; Sire—Narayan ; Dam—Lalagi ; Dam's best lactation—7,425 lb. ; Weight on 21-12-1935—1,164 lb. (Photographed on 13-12-1935).

Reproduced from *Agriculture and Livestock in India,* Vol. VI, pt. 6, (1936).

BURT : *Agriculture and Animal Husbandry in India.* PLATE XII.



AN OUTLINE OF ARCHÆOLOGY IN INDIA.

By

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CONTENTS.

Of all the field sciences included in this volume archæology dealing with the vicissitudes of man's culture throughout the ages is the last. In a country of the size and antiquity of India the sum total of man's endeavours throughout the millennia of its existence must baffle any attempt to summarize the main features of the story of India's culture through the ages which is here sketched within the limits of available space.

Stone Age

The story of India's culture begins in Peninsular India when palæolithic man wielded rough hewn stone implements in the valleys of Narmada, Godavari and other river systems of the South. The oldest finds to which a date can be assigned on geological (but not on archæological) grounds is the find of a 'boucher' at Bhutra in the Narsinghpur District of the Central Provinces. Bones of extinct mammals were found associated with this rough stone implement. Another important find of a slightly more advanced technique is an agate chip found in the bed of the Godavari at Mungi in the Ahmednagar District opposite Paithan in the Nizam's Dominions. Various other finds in the Nizam's Dominions, Mysore, Shevaroy hills and the Jawadi hills and in the ravine beds in the Madras Presidency testify to the existence and the habitat and wanderings of palæolithic man. The neolithic stage is more widespread and embraces finds of flints in Upper Sind and in the

Sohan valley in the Northern Punjab and the Assam hills in the north-east, while South India again continues to be prominent on the map of neolithic India. Systematic investigation of the typical neolithic sites of the advanced stage has yet to be undertaken and may reveal the steps by which man recorded the tremendous advance which is a feature of the next or chalcolithic stage. It is noteworthy that in South India the iron age succeeds closely in the wake of the neolithic culture without any intervening copper or bronze age, which is of so great importance in North-Western India.

Mohenjodaro and the Indus Culture

Fifteen years ago it appeared as if the historic civilization of India descended upon an aboriginal population just introduced to metal tools, if not still wielding implements and weapons fashioned from stone. The hoary civilization of the valleys of the Nile and Euphrates hardly seemed to have any counterpart in the valleys of the Indus and the Ganges, although the physical conditions in the latter appeared to be as conducive of rearing a robust population and as extensive and advanced a civilization as any in the ancient world. The province of Sind, which, but for a number of Buddhist establishments barely 1,500 years old, was then perhaps the most unimportant part of India to the archæologist, has now been brought into its own as one containing the richest and most important sites in the country. Mohenjodaro, the premier ancient city of Sind, is not only the oldest known but also the best preserved site in India, which, more than any other discovery in Indian archæology has stimulated the interest of scientists and scholars. The origin of every aspect of Indian art and culture has now to be traced to Mohenjodaro times. Thus the famous limestone statuette of a bearded man draped in an upper garment with trefoil embroidery (Plate XIII) is the earliest attempt in Indian sculpture. The art of the seal-cutter and jeweller, the conch-worker and lapidary, the skill of the town-planner and house-designer and various other advances in the technical arts indicate the high level of the Indus valley civilization. Investigations in other parts of Sind, Baluchistan, the Punjab and Kathiawar have brought to light a wealth of other smaller sites, which well illustrate the scope and extent of this ancient Indian culture. Some trial excavations at Nal and other places in Baluchistan and recent work by the American expedition at Chanhudaro have thrown more light on certain other aspects and phases of this culture of the Indus valley. In the Punjab the city of Harappa, more extensive but less well-preserved than Mohenjodaro has yielded important material, particularly in the shape of a cemetery. It is undoubted that if work is extended to other sites in Punjab and Sind they will yield further valuable material for the reconstruction of this remarkable civilization. In the North-West Frontier Province the discovery of certain terra cottas from the lower strata of certain mounds near Charsadda is

being ascribed to the same early period, and if this opinion is confirmed by further researches, it will undoubtedly prove the strong root which the civilization had taken throughout the Indus basin.

Copper Age in North India

The continuation of the ancient Indian culture from the Indus valley to the Gangetic plains has not yet been clearly traced, but there can be no doubt that the next few years will see the links between the prehistoric and historic cultures of India firmly established. In Northern India the age of copper and bronze seems to have continued for a sufficiently long period, but apart from implements, which have been brought to light by chance finds, no systematic excavation has yet been attempted. The most common implements are shouldered celts, harpoons, axes, spear heads and swords, which have been discovered at various places in the United Provinces. The most important and biggest hoard of prehistoric metal implements and objects came from Gungeria of the Balagarh District of the Central Provinces. It contained as many as 421 specimens of almost pure metal and 102 laminæ of silver, exhibiting an amazing variety of implements. More work if done at a suitable site in the United or Central Provinces is likely to establish connection between these copper age finds and the Indus civilization.

Gap in India's History

The correlation of the early Vedic and Brahmanic literature which is localized with any archæological remains in the Punjab and United Provinces has not yet been established and the entire epoch from about 2,500 B.C. to 500 B.C. is a strange gap in Indian cultural continuity. The immigration of the Aryans into India and their colonization and gradual settlement over the whole expanse of Northern India has undoubtedly to be fitted somewhere into this period, but archæology has so far been unable to settle the chronology of the principal events and occurrences referred to in the vast Vedic and epic literature.

One group of monuments, which was long believed to belong to the Vedic age, is the so-called Vedic burial cemetery at Lauriya Nandangarh in Bihar. Recent work at this site has proved that the mounds at this place do not go back to any high antiquity, although some very interesting and extensive structures showing a novel type of architecture have been found. Rajgir, the ancient capital of Magadha, is another place reputed to have existed before the time of Buddha, but beyond the city walls of crude cyclopean masonry, which may date anywhere from the 7th century to the 3rd century B.C., no definite relics of an early age have been discovered.

Dawn of Historic Age

When light again emerges on Indian history the Indo-Aryan civilization has already worn itself out and a protest against the orthodox Brahmanical religion had already made itself felt in the shape of Buddhism and Jainism. The earlier monuments of these

faiths pertain to the third and second centuries B.C. and it was the royal patronage of the Mauryan emperors Aśoka and Daśaratha and that of the Kings of Orissa such as Kharavela that enabled these protestant faiths to erect monuments of outstanding importance. From this time onwards the main currents of Indian history are quite clear and the systematic field work of the last thirty years has enabled archæologists to study the tangible remains of the different periods and in the various historic tracts of India.

Mauryan Art and Architecture

Before the discovery of the Indus civilization, the monuments of the Mauryan period, then the earliest known in India, provide a great stumbling block to the students of architecture. With the distant background provided by the Indus Valley remains, it is not now difficult to conceive of the achievements of Mauryan artists as the products of an age-long tradition enlivened by fresh contact with the Perso-Greek world. The results of regular excavations at Pāṭaliputra (roughly modern Patna) and Sarnath, as also the number of artistic objects brought to light in course of the sewage operations at Patna, leave no doubt about the flourishing state of arts in the Mauryan age. In one respect, viz., the manufacture of terra cotta figurines, there seems to have been maintained a remarkably high level of technique and there is little doubt that in other respects similar will be found to be the case. What is indisputable, however, is the fact that stone carving and stone architecture was for the first time attempted in the Mauryan period, and in some of the examples of the latter class, timber prototypes are postulated. The caves at Barabar in Gaya District, excavated for the Ājīvika sect of ascetics in the time of Daśaratha, the grandson of the famous Buddhist Emperor Aśoka, are an outstanding example of the cave architecture of this period. In sculpture, the capitals, which Aśoka provided for his pillars, the best example of which is the exquisite Sarnath capital (Plate XIV), represent the art of the Imperial court, which does not seem to have much affected the trend of popular art. The latter is represented by certain statues from Patna, Besnagar (Central India) and Parkham (near Muttra) which are characterized by a feeling of volume and mass, though in point of sculptural modelling it represents a primitive conception.

Bharhut and Śuṅga Art

In the time of the Śuṅgas, who came into power during the 2nd century B.C., Indian art made further strides towards development, and the Buddhist stūpa at Bharhut (Central India) which is the most remarkable monument of this period, illustrates its simple but expressive character. The fragments of the railing around the Bharhut stūpa, which are now kept in the Indian Museum, Calcutta, show how the artists have succeeded in narrating the stories of Buddha's life and his former births, both human and animal, with a naive beauty all its own, in spite of technical shortcomings in modelling and perspective. Among the series depicted in the

panels, special mention may be made of the dream of Māyā, Buddha's mother, the royal processions of the kings of Rajgir and Śrāvastī visiting the Buddha, the acquisition of the Jetavana park by the merchant Anāthapiṇḍaka, who had the whole ground strewn with gold coins, and the former lives of Buddha as a monkey, a deer or an elephant. Besides these several other reliefs on the railing pillars depicting demi-gods and *yakshas*, male and female, which no doubt occupied much space in popular imagination are noteworthy.

Sāñchī and Mathurā

The magnificent Buddhist remains at Sāñchī in the Bhopal State are the best preserved in the series of early Buddhist monuments in India. Here the main stūpa, which was probably built by the Mauryan Emperor Aśoka, was later faced with stone and surrounded by a stone railing pierced by four gateways, one on each cardinal point, which are elaborately decorated with figure sculptures and bas-reliefs illustrative of Buddha's life or the *jātaka* legends. The art of Sāñchī shows a still further development in technical skill and more conventionality and in itself covers a century-long development which brings us to the beginning of the Christian era. Another great centre of art, which commenced its activity at this period but which was to attain phenomenal development in the succeeding centuries, is Mathurā. Here the abundance of stone in the neighbourhood seems to have been availed of by all the religious persuasions alike, and some of the earliest Brahmanical and Jaina images in India were manufactured at this centre. In fact, Mathurā is one of the most important and prolific centres of sculpture throughout Northern India.

The Graeco-Buddhist School of Gandhāra

The domination of the Graeco-Bactrian, Scythian and Parthian rulers in the North-west of India introduced a flood of new artistic ideas based on the Hellenistic ideals of beauty. This gave rise to a new school in the North-west of India popularly known as the Graeco-Buddhist school of Gandhāra which rose in the 1st-2nd centuries of the Christian era. One innovation introduced by the Gandhāra school was the image of the Buddha, which was not hitherto attempted by the sculptors of the indigenous school, the presence of the Buddha being always indicated by means of symbolic representations. The Museums at Lahore and Peshawar and, to a less extent, the Indian Museum, Calcutta, bear witness to the intense devotion of the Buddhists of North-west India and the prolific activity of the sculptors trained in Hellenistic traditions. The impact of these new forces that were making themselves felt in the North-west reached Mathurā along with the Kushān domination in 2nd century A.D., and in due course extended further inland both to the East and South. Some of the Gandhāra motifs are to be found slightly modified in the products of the Buddhist school in the Krishna Valley as at Amarāvatī and Nāgārjunikoṇḍa in the

Guntur District of the Madras Presidency. On the whole, however, the Hellenistic element in Indian art was completely absorbed by the 4th century A.D. when under the stimulus of the Gupta Emperors, Indian art reached its classical age.

Western India Caves

In Western India the growth of Hinduism has left few other monuments except the rock cut caves which offer fascinating material for the student of architecture. The geological formation of Western India with its deep strata of volcanic trap rock is responsible for the concentration of more than 80 per cent. of India's cave temples in this part of the country. The earliest among the series are the groups at Bhaja and Karla near Poona, the Chaitya Hall at the latter place being one of the most impressive of the series. Both in the decoration of the façades as well as the interior arrangements, these groups of caves at Nasik, Kanheri and other places in the Bombay Presidency offer much admirable material to the student. Their dates are fixed by a large number of inscriptions of the Āndhra kings and the Western Kshatrapas occurring in them who lived in the 1st and 2nd centuries A.D. Some of these continued to be inhabited till the Gupta epoch and the world renowned caves of Ajanta in the Nizam's Dominions preserve the best known examples of Indian paintings which are unparalleled in the East.

Gupta and Mediæval Art

The rise of the Gupta dynasty in Northern India in the 4th century A.D. ushered in the golden age of Indian art in every branch of fine arts. Indian genius had this time fully assimilated all that was best in the foreign influences that were brought to bear during the previous centuries and a thoughtful synthesis resulted in which the best impulses of Indian art were given full expression. The keynote of the work of this period was a broad intellectualism and a balance between spiritual thought and material expression. The best sculptures of this period have been found at Sarnath, Mathurā and Deogarh in the United Provinces, while examples of terra cotta and minor arts have been found in practically all the excavations in North India. In the field of religion, the steady ascendency of the Brahmanical faith over the Buddhist schools began in the Gupta period and gradually gained rapid ground particularly in Western and Southern India. In Eastern India, however, Buddhism continued to hold its ground in Bihar and Bengal until it was finally ousted by the onrush of Islamic invasion in the 12th century A.D.

Brahmanical temples in Western and Southern India

In Western India, the caves at Badami in the Bijapur District, the capital of the Chālukya kings, the magnificent Kailāsa temple at Ellora in the Nizam's Dominions built in the 8th century, and the Elephanta caves near Bombay with some of the most powerful and expressive sculptures

in India, are outstanding examples of the enthusiastic activity of the followers of the revived Brahmanical religion. In Southern India the seven Pagodas at Mahabalipuram and the temples at Conjeevaram, both near Madras, show the spirit and vigour of art under the Pallava kings. The seven Pagodas, although cut out of living rock, are perfect examples of structural temples, and the huge bas-reliefs representing the animated scenes of the descent of the Ganges (Plate XV) are wonderful specimens of Pallava art. The foundations of South Indian art and architecture laid by the Pallavas were later to provide the superstructure for the great architectural efforts under the Cholas and still later under the Vijayanagara empire. The great examples of Indian temple architecture are provided by the temples in the South Indian or Dravidian style at such centres as Tanjore, Chidambaram, Madura, Trichinopoly and Ramesvaram.

Later Buddhism in Eastern India

In Eastern India, the great Buddhist centre from which much of the cultural expansion of Indian Buddhism in Northern and Eastern countries emanated was Nālandā. An idea of the splendour and eminence of this place can now be had from the excavated stūpas (Plate XVI) and monasteries and the antiquities, particularly the magnificent collection of bronzes, recovered from the ruins. The remains at Paharpur in Bengal consisting of a gigantic central temple surrounded by a very extensive monastery (Plate XVII) afford a glimpse of Bengal of the pre-Muslim epoch, of which no extant remains have survived. In fact, field archæology has had a much wider scope in the plains of Northern India where very few remains of architecture, dating before the Muslim invasion, have survived.

Styles of temple architecture

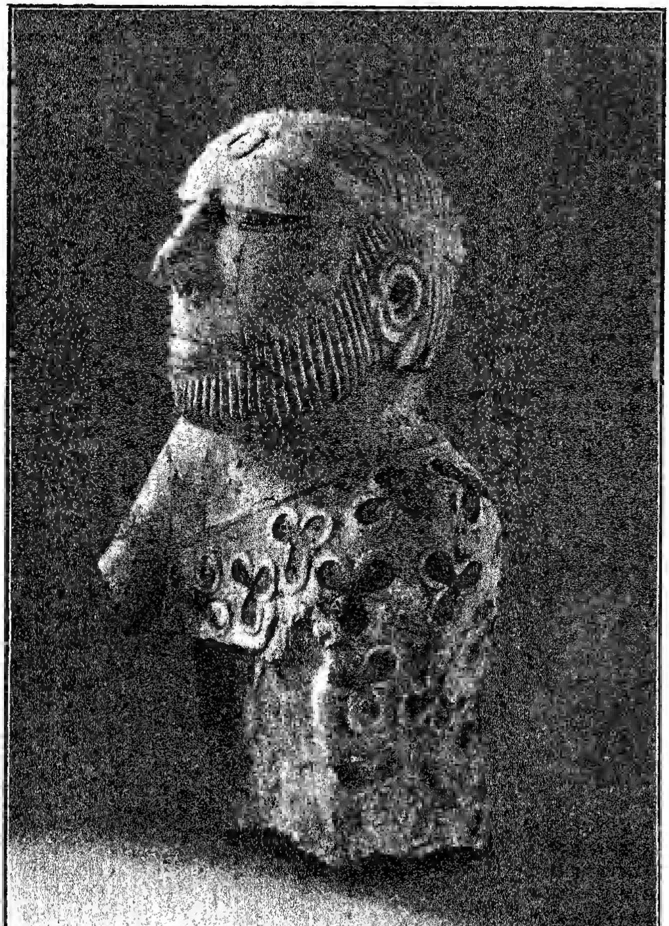
In Central India a number of local schools of art register a steady decline of the ideals and achievements of the Gupta times. Among architectural ideas, the most prominent is the emergence of the *śikhara* type of temple with its elongated spire and sculptural decoration as compared with the simple flat-roofed temple of the Gupta period with its restraint and dignity. Several regional types of temples can be studied, one being located at Khajuraho in Central India and another and a more magnificent one at Bhuvanesvara in Orissa. The temples in Gujerat and Rajputana, among which those dedicated to the Jaina faith are predominant, form an important regional type, while in the Deccan and Carnatic there is a widely prevalent style of architecture coming down from the times of the Chālukya kings of the Deccan. In Mysore the temples at Belur and Somanathpur form prominent examples of the local style of architecture which is known after the Hoysala rulers.

Islamic Monuments

The emergence of the forces of Islam in Northern India in the 12th century put an end to the indigenous artistic and sculptural activities, but in the earlier products of Islamic monuments such as the Great Mosque built by Qutb-ud-din at Delhi, it is evident that the dominant features of the art of the conquered Hindus made themselves felt in the monuments of the alien faith. Hereafter Islamic architecture manifested itself into several local styles, each characterized by local peculiarities in which the indigenous element was not slow to assert itself. Thus the splendour and effeminate beauty of the Gujerat carving is a prominent feature of the mosques at Ahmedabad, while in Bengal the monuments at Gaur and Pandua reflect in no uncertain manner the langour and decadence of the late Pāla work in Bengal. Some of the local styles such as those at Mandu in Malwa and particularly at Bijapur strike an original and strong note. In and around Delhi and Agra the advent of the Moghuls ushered in an era of architectural magnificence, of which the tomb of Humayun at Delhi, the splendid remains at Fatehpur Sikri built by Akbar and the great Taj Mahal are the most magnificent examples.

EXPLANATION OF PLATE XIII.

Limestone statuette from Mohenjodaro. This is the only piece of sculpture recovered from the Indus Valley excavations. It represents a bearded man, probably of aristocratic stock as is evident from the upper garment which he is wearing. This garment or shawl is embroidered with trefoil leaves which are picked out in ochre red. The attempt shows the primitive state of the sculptor's art in the Indus Valley as contrasted with the contemporary sculpture of Egypt and Sumer and the advance in other technical arts such as that of the potter and seal-cutter in India itself.



EXPLANATION OF PLATE XIV.

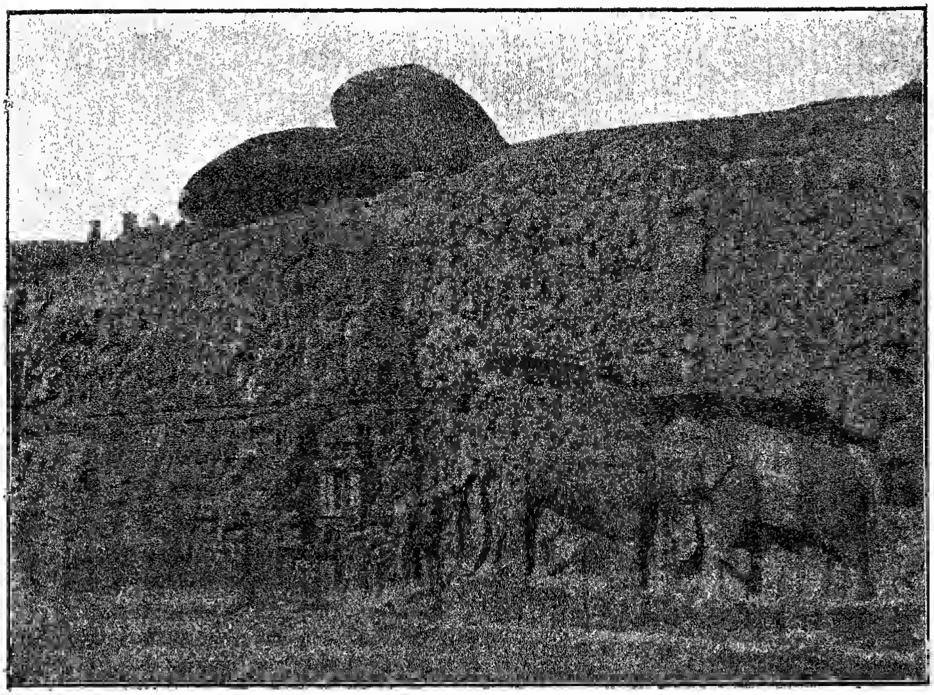
Polished stone capital found at Sarnath in course of excavation. It originally crowned the monolithic pillar which Aśoka, the great Buddhist Emperor, set up at the place where the great founder of the Buddhist religion preached his first sermon. The excellent polish and the technical perfection of this piece, particularly the lions crowning the piece and the animals on the abacus, entitle this piece to be considered among the masterpieces of Indian art. The animals on the abacus are an elephant, a bull, a horse and a lion, which are interpreted as symbolizing the conception, birth, migration and enlightenment of the Buddha.

DIKSHIT : *Archæology in India.* PLATE XIV.

EXPLANATION OF PLATE XV.

Rock carvings at Mahabalipuram, popularly known as the Seven Pagodas near Madras. These wonderful specimens of Pallava art are referred to the 6th-7th century A.D. The present relief represents the scene of the descent of the Ganges which was brought down from heaven through the efforts of King Bhagīratha. A number of animated scenes with men and animals are depicted on either side of the river which itself is shown as a shallow depression through which actually water passed from the top of the rock.

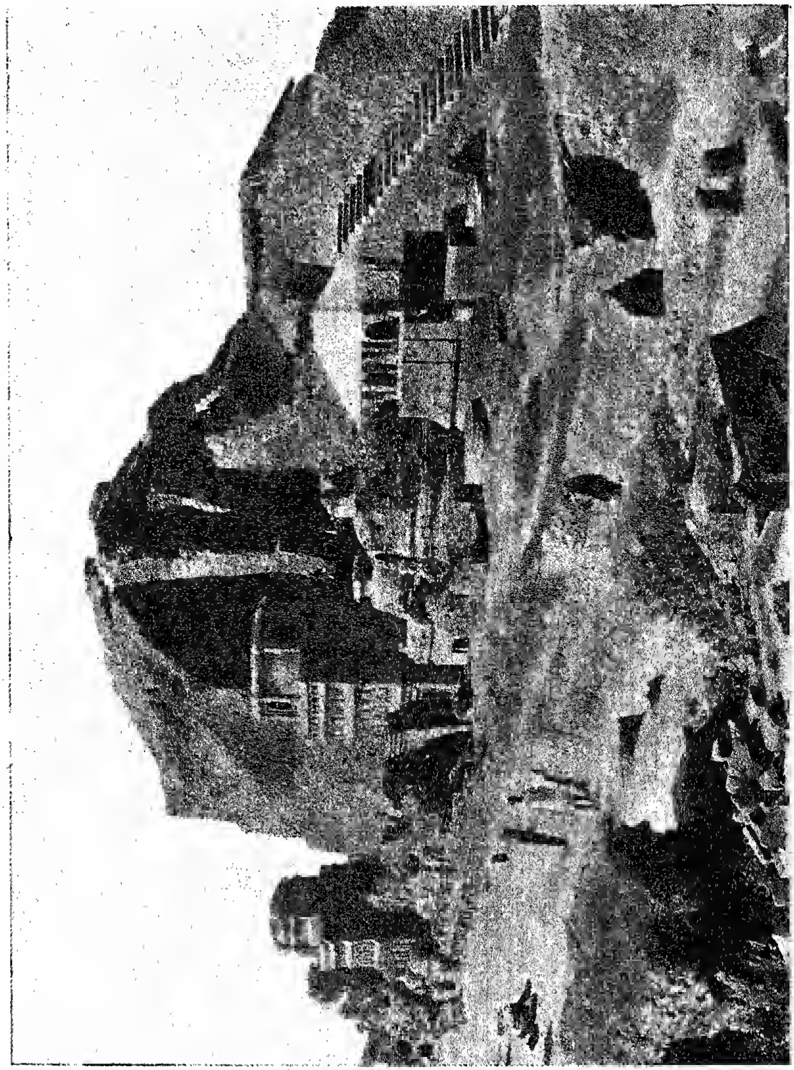
DIKSHIT : *Archæology in India.* PLATE XV.



EXPLANATION OF PLATE XVI.

A view of the great temple at Nālandā, which with its numerous temples and monasteries was the biggest centre of Buddhism from 6th to 11th century A.D. The main temple, originally constructed about the 5th or 6th century A.D., underwent no less than six renovations, all of which have been brought to light by a careful excavation of the stupendous mass. The towers at the corners have been decorated with figures in stucco. The finds of stone and particularly bronze images, besides inscriptions, seals, etc., at Nālandā constitute a record and have been very valuable for the reconstruction of the history of art and religion in Eastern India.

DIKSHIT: *Archæology in India.* PLATE XVI.



EXPLANATION OF PLATE XVII.

The great temple at Paharpur in the Rajshahi District of North Bengal. The excavations conducted here for about a decade have brought to light the remains of a magnificent temple surrounded by the largest single monastery in India with 180 rooms. The plan of the central temple with its multiple terraces, recessed angles and friezes of terra cotta plaques is unique in India but has been widely followed in Burma, Siam and Java. In the basement a number of stone sculptures representing Brahmanical deities and the stories of the exploits of Kṛishṇa—the earliest in Bengal—have been found. The establishment was founded by Dharmapāla of the Pāla dynasty in the 8th century and continued till the 12th century A.D.

K HIT : *Archæology in India.* PLATE XVII.